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Publié avec le concours financier de l'U. N. E. S. C. O.

Bulletin volcanologique

ORGANE DE

l'Association de Volcanologie

de l'Union géodésique et géophysique internationale

Publié par le Secrétaire général

FRANCESCO SIGNORE

Série II — Tome XVIII

Comptes rendus
de la X^e Assemblée Générale à Rome
14-25 Septembre 1954
III^e Partie

B. V.

NAPOLI
Stabilimento Tipografico Francesco Giannini & Figli
Via Cisterna dell'Olio
1956

BULLETIN VOLCANOLOGIQUE

Organe de l'ASSOCIATION DE VOLCANOLOGIE
de l'Union géodésique et géophysique internationale.
Série II - Tome XVIII - 1956

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(Voir la suite à p. 3 de la couverture)

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62-16458

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B 874
Ser. 2
v. 18-19

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A Physiographic Reconnaissance of Some Volcanic Provinces in North Queensland, Australia.

(With 6 text-figures and 5 plates)

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I. Introduction

Extensive areas of peripherally dissected basalt plains and plateaux in which structural bench features are widely developed are known in northern Queensland. Within the Leichhardt-Gilbert Area, as defined and surveyed by the Land Research and Regional Survey Section of C.S.I.R.O., the basalts are confined to the eastern margins where they form four distinct provinces, shown in Fig. 1, which cover a total area of about 7,000 square miles. Although there are other areas of basalt in north Queensland, those of the Leichhardt-Gilbert Area are the only ones the writer has had the opportunity to examine and it is to these that this paper is devoted. The basalt areas were examined during relatively brief field traverses, and mapping has been accomplished by the extrapolation of field data on aerial photographs. It is to be emphasised that this survey is of a reconnaissance type.

The basalts are olivine basalts and thus the provinces are quite commonplace petrologically; for all over the world and throughout geological time olivine basalt is the most common volcanic rock and the largest volcanic mountains and plains are built of successive sheets of this basalt with minor occurrences of other lavas. The basalts are markedly vesicular and amygdaloidal with vivianite, zeolites, and various forms of chalcedonic silica commonly occurring in the amygdales.

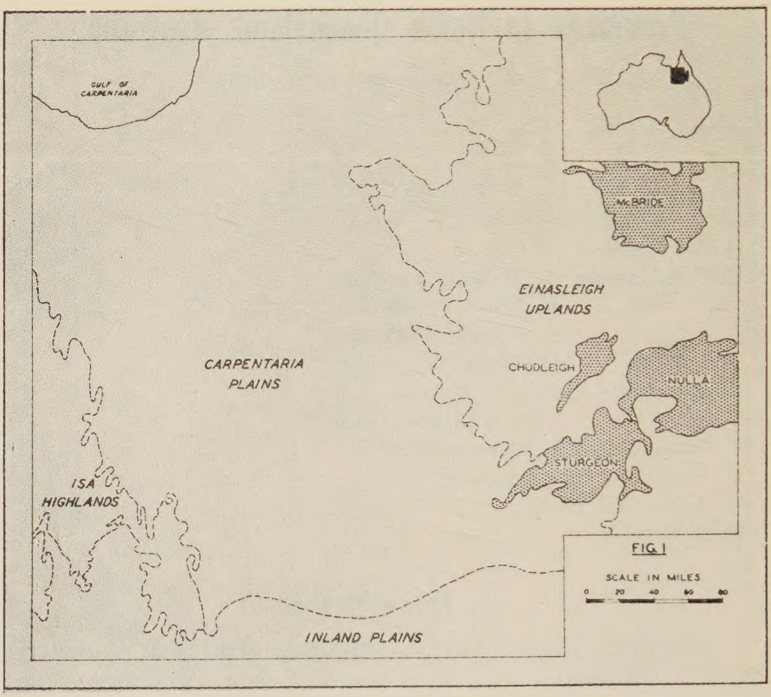


FIG. 1

On the margins of the basalt sheets the thickness of the basalt is always 125 feet or less, and though this figure undoubtedly increases towards the centres of the sheets, no data is as yet available.

II. Physiography

Despite quite important regional contrasts, all four provinces have much in common and with this factor in mind it is proposed first to describe fully the McBride Province and then to detail the various contrasted features in the other areas.

A. - McBride Province

The McBride volcanic province, shown in Fig. 2, extends over 2,000 square miles between Conjuboy Homestead, Herbert Falls, Mt. Surprise and Einasleigh, and is traversed by the Hann Highway from north to south.

General. — Essentially the district consists of a great dome with about 800 feet relief amplitude from margin to crest. Thus on the Hann Highway the level rises from about 2,000 feet above present sea-level to a maximum of the order of 2,800 feet at the crest of the dome, while heights in excess of 3,000 feet are attained in some limited localities away from the Hann.

The dome consists of layer upon layer of basalt representing successive flows of lava. There were periods of weathering of considerable duration between some of the major flows, and about one and a half miles south of Rosella Plains Homestead, for instance, the section shown in Fig. 3 can be observed. The basalt B flowed and consolidated on an uneven surface eroded in A, and for the basalt A to have been so extensively weathered there was clearly a period of exposure to sub-aerial processes between the consolidation of A and the extrusion of B. Further evidence of inter-flow sub-aerial denudation can be seen to the south-west of Mt. McBride where a comparatively recent extrusion flowed down valleys eroded in an earlier basalt towards the Burdekin valley near Valley of Lagoons and Reedy Brook Homesteads.

Drainage. — On the north, east and west sides, the drainage is radial off the dome, and the streams are consequents, but to the south there lie the high ranges and up-

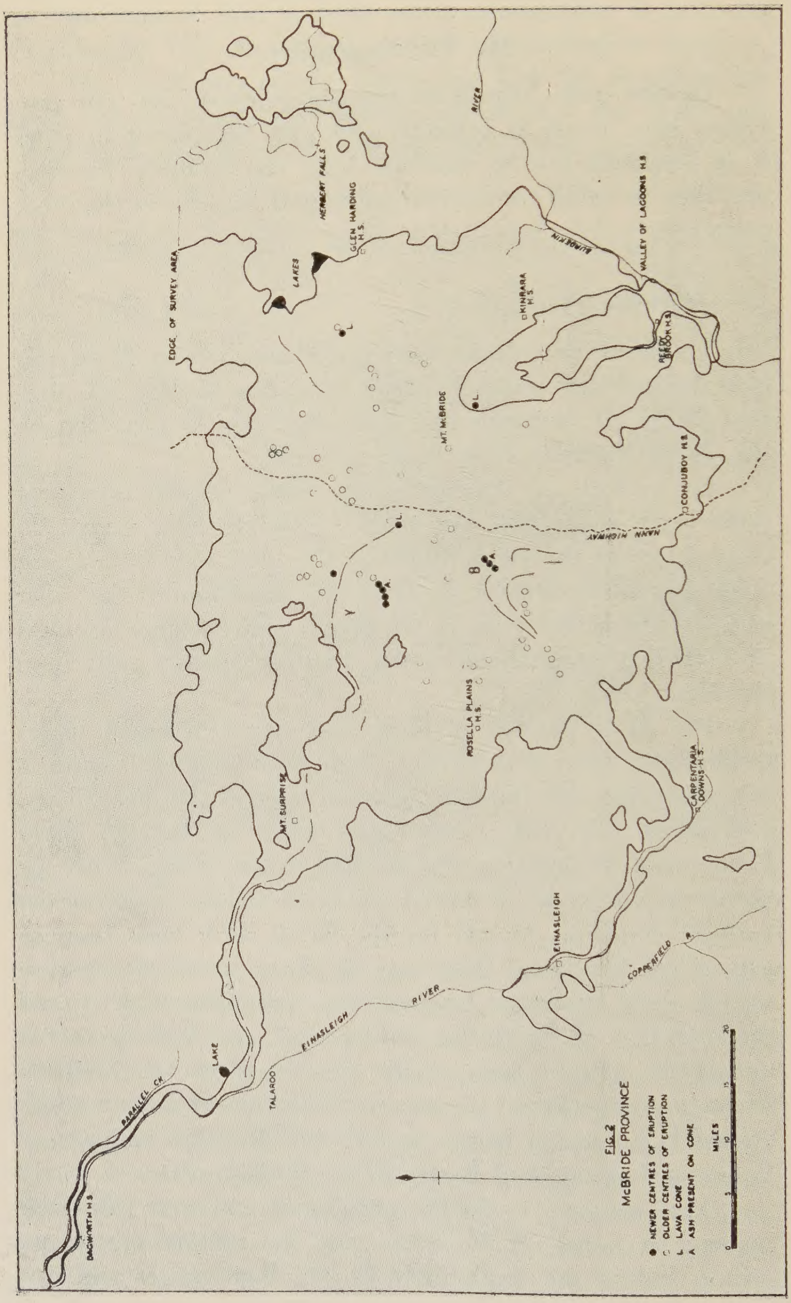


FIG. 2
McBRIDE PROVINCE

lands of the Divide. Here the general level is in excess of that of the edge of the basalt dome and many streams flow off the Divide and down toward the basalt where they join the radial consequent streams, sometimes at an acute angle. The dome is dissected peripherally and some of the major pre-basaltic valleys are occupied by tongues of basalt; the Einasleigh between Carpentaria Downs Homestead and Einasleigh Township and between Talaroo Crossing and Dagworth Homestead may be cited as an instance.

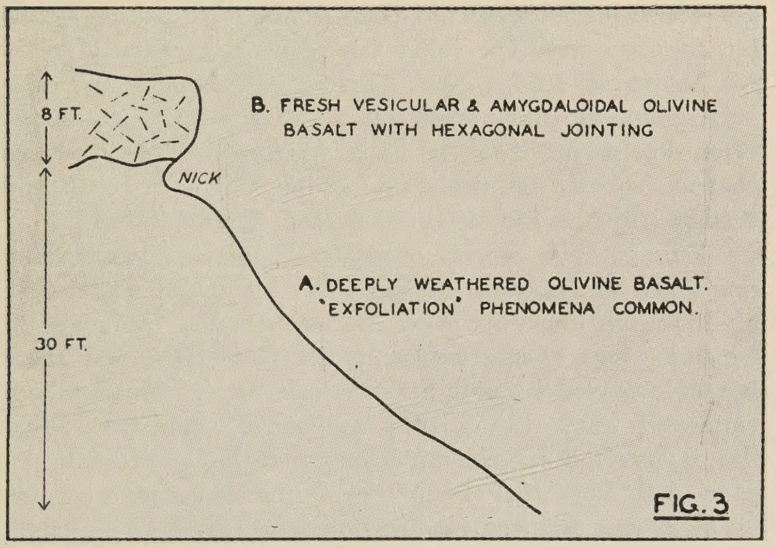

8 FT.
B. FRESH VESICULAR & AMYGDALOIDAL OLIVINE BASALT WITH HEXAGONAL JOINTING
NICK
A. DEEPLY WEATHERED OLIVINE BASALT. 'EXFOLIATION' PHENOMENA COMMON.
30 FT.

FIG. 3

On the dome itself most of the streams are consequent, but some flow parallel with the structural scarps which are mentioned below; these streams are fed by springs which debouch from between lava flows and tend to flow at an obtuse angle to the normal consequent streams. The streams tend to form a concentric pattern around the crest of the dome, running parallel with the flows which emanate from this crest.

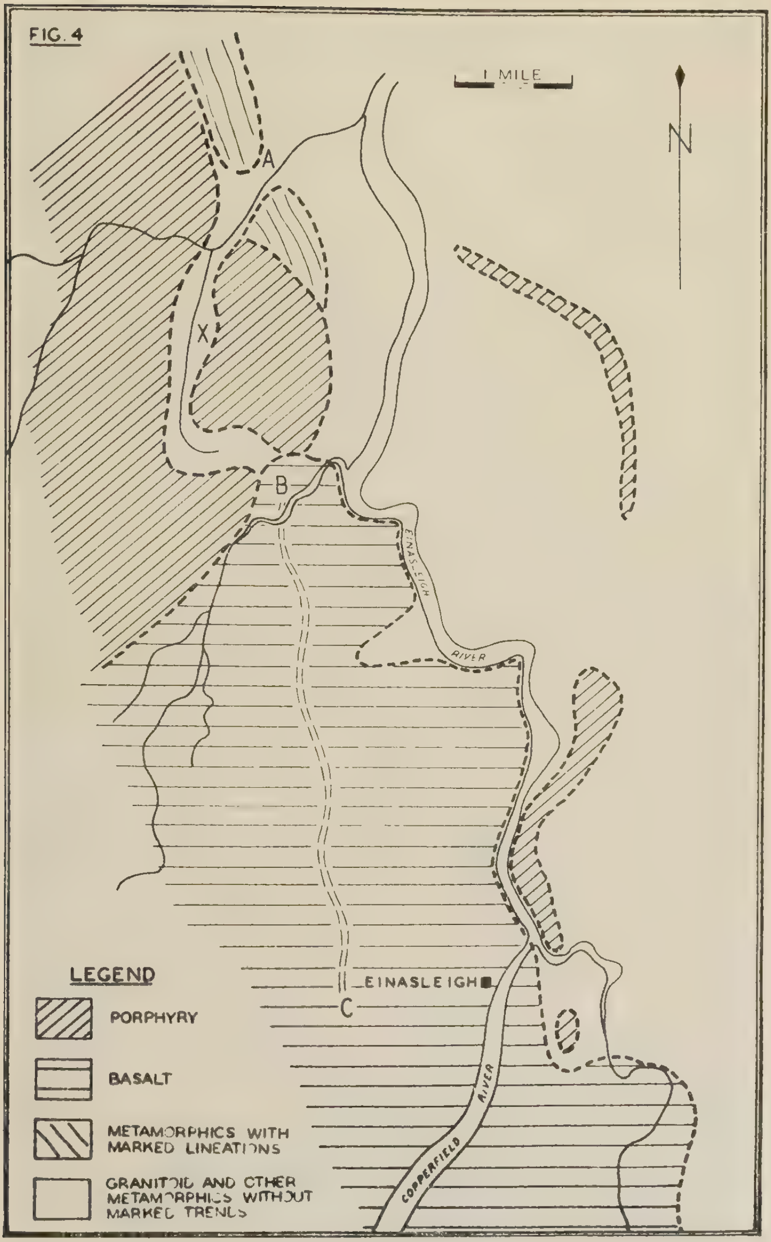
The usual basalt stream is a shallow boulder strewn waterway, but as soon as the stream leaves the basalt areas, or as soon as the stream penetrates the base of the basalt and reaches the underlying strata, marked incision takes place.

In the Einasleigh valley examples of drainage modification can be discerned and around the periphery of the basalt several basalt dammed lakes have formed. Examples of this latter phenomenon occur north of Talaroo Crossing and in the Glen Harding area. Between the Crossing and Dagworth an old pre-basalt valley is now occupied by a tongue of basalt which flowed westward from centres of extrusion in the Mt. Surprise area. The valley flow caused inversion of relief (de MARTONNE, 1935, p. 744; COTTON, 1952, p. 355) and drainage diversion; and instead of the river occupying the position now occupied by the basalt tongue there are now two channels situated on either side of the tongue of basalt and occupied by the Einasleigh River and Parallel Creek.

Turning to a second example of drainage modification due to basalt extrusion, there is, about a dozen miles north of Einasleigh township, a deeply incised valley (X in Fig. 4) which has been abandoned by the Einasleigh River and which is now occupied by only a very small stream. The southern entrance is blocked by a basalt flow and it would appear that the pre-basalt Einasleigh River occupied the approximate position A-B-C and that the flow of the basalt caused inversion of relief and drainage modification (see Fig. 5). This modification of drainage caused the pre-basalt Einasleigh valley to fall largely into disuse. Small streams flow into the abandoned valley from the porphyry areas and sections with an abrupt change from pure to coarse material as witness to an alteration in conditions can be seen. The change is the result of the diversion of the Einasleigh River, the deprivation of a supply of fine - medium textured material typical of a major river, and its replacement by the very coarse, localised, material characteristic of steep mountainside torrents.

Landforms. — The basalt dome comprises a series of structurally stepped plains and plateaux, the stepped effect being due to the separation of plains at different levels by scarps which are the consolidated fronts of lava flows, and which, though they may attain a height of 50 feet, are more

FIG. 4


1 MILE
N
A
X
B
C
EINASLEIGH RIVER
EINASLEIGH
COPPERFIELD RIVER
LEGEND
PORPHYRY
BASALT
METAMORPHICS WITH MARKED LINEATIONS
GRANITOID AND OTHER METAMORPHICS WITHOUT MARKED TRENDS

commonly of the order of 20-30 feet. Over a large part of the area soils have developed and frequently black swamp soils have accumulated in depressions separated by rough low stony ridges or rises. Some of the stony rises exhibit collapse structures and other phenomena essentially similar to those described by Skeates and James (1937). Caverns are widespread, and are frequently encountered in the area between Mt. McBride and the Burdekin valley delineated in Fig. 2.

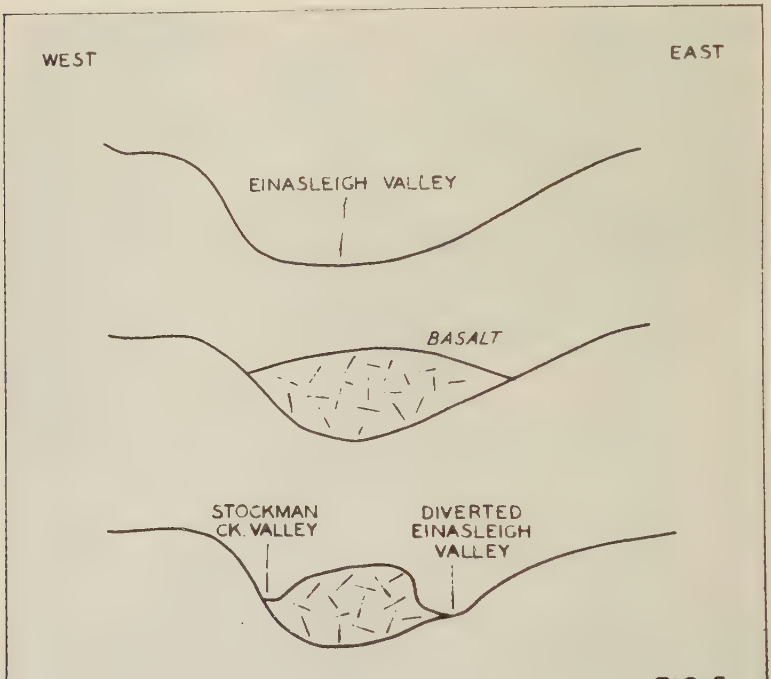


FIG. 5

This is an area in which no soils have developed, being occupied entirely by rocky outcrops of scoriaceous lava displaying excellent aa and pahoehoe structures. Where this fresh lava, termed here the Kinrara basalt, reaches the Burdekin valley at Reedy Brook and Valley of Lagoons, lava pavements have formed and drainage has been impeded.

There can be no doubt that the basalt areas are relatively resistant areas: the reason for this is that basalt flows, being well jointed, are extremely pervious and have a propensity for « swallowing » water. Thus run-off is reduced, and the basaltic areas are relatively well-preserved from erosion.

Numerous ancient centres of eruption occur in many localities of the dome and are indicated in Fig. 2 where a distinction is made between the badly weathered and eroded, more ancient, volcanic cones, and the more recent, better preserved, ones. About sixty centres of eruption have been recognised in the McBride Province, and it is of value to examine their distribution. With two possible exceptions — and one of these (Mt. Stockman, near Einasleigh Township (see MARKS, 1911, p. 9)) is not a definite ancient volcanic centre — the ancient foci, concentrated within an ovoid area situated astride the Hann Highway, cannot be aligned with any major trends. If, as JAGGAR (1920, pp. 169-170) opined, the hypomagma — the sub-surface relatively immobile magma — rises through rift zones to give something in the nature of a fissure swarm, there should be trends discernible, always assuming that the rift zones follow regional tectonic directions. The predominant regional trend hereabouts is north-north-west - south-south-east, although Siluro-Devonian strata which occur to the south of the province have a very clear north-east - south-west lineation. However, with two exceptions, no lineaments acceptable to the statistician can be distinguished in this province; the exceptions to which reference is made occur in the vicinity of Y in Fig. 2:

(1) there is a quite clear arc along which several centres of eruption occur,

(2) there is a clear arcuate fissure some 25 miles in length with a centre of eruption at its south-east end.

Most of the centres of eruption are composed of lava, ash and tuff being notably absent in the majority of cases. Some centres display excellent diatremes * and some of these

---

* Defined by COTTON (*op. cit.* pp. 220-221) as « vents opened by explosions ». HILLS (*personal communication*), however, uses the term for cones in which the central core or plug has sunk or collapsed but whether or not this structure is present in the Queensland examples cannot be discerned until dissection has occurred.

diatremes are occupied by lakes. Coulées have been observed and adventive cones occur in two areas, near Y and B of Fig. 2. Of these, the first is known as Mt. Tabletop and is a lava cone of the Mauna Loa type on the flanks of which five adventive cones have developed (see Plates I and II). The more recent centres exhibit forms which are variable, yet of a single general conical type (see for example Plate III), while foci of greater antiquity, found in various states of dissection, also appear to have had the same general form as the newer features. Some scoriocones are present, (see for instance Plate IV) and these possess no diatremes.

B. - Nulla Province

The Nulla Province, some 2,600 square miles in extent and shown in Fig. 6, has much in common with the northern McBride volcanic area; it has the overall form of a low dome composed of a large number of successive flows and the most general landforms are structural benches with flow-front scarps; there are cones representing former centres of volcanic eruption and a considerable area is occupied by quite unweathered basalt; extensive peripheral dissection has taken place and there are marginal drainage modifications.

The area of fresher basalt (termed herein the Toomba basalt) occupies an area to the east-north-east of Lolworth Homestead and to the north of Toomba Homestead and is bounded by the scarp known as « The Great Basalt Wall ». The newer basalt is extremely vesicular and clinkery, has a well-developed ropy structure, and forms a low irregular plateau some 50-100 feet above the general plain level. It is bounded by an irregular scarp, the consolidated and cooled front of the lava flow.

The basalt areas have suffered considerable denudation as the result of stream dissection in the Mary Vale and Wando Vale areas and deep gorges occur in association with the rivers in the marginal areas.

Notwithstanding many common features, there are very definite regional contrasts between the McBride and Nulla Provinces; in particular, peripheral dissection is more marked

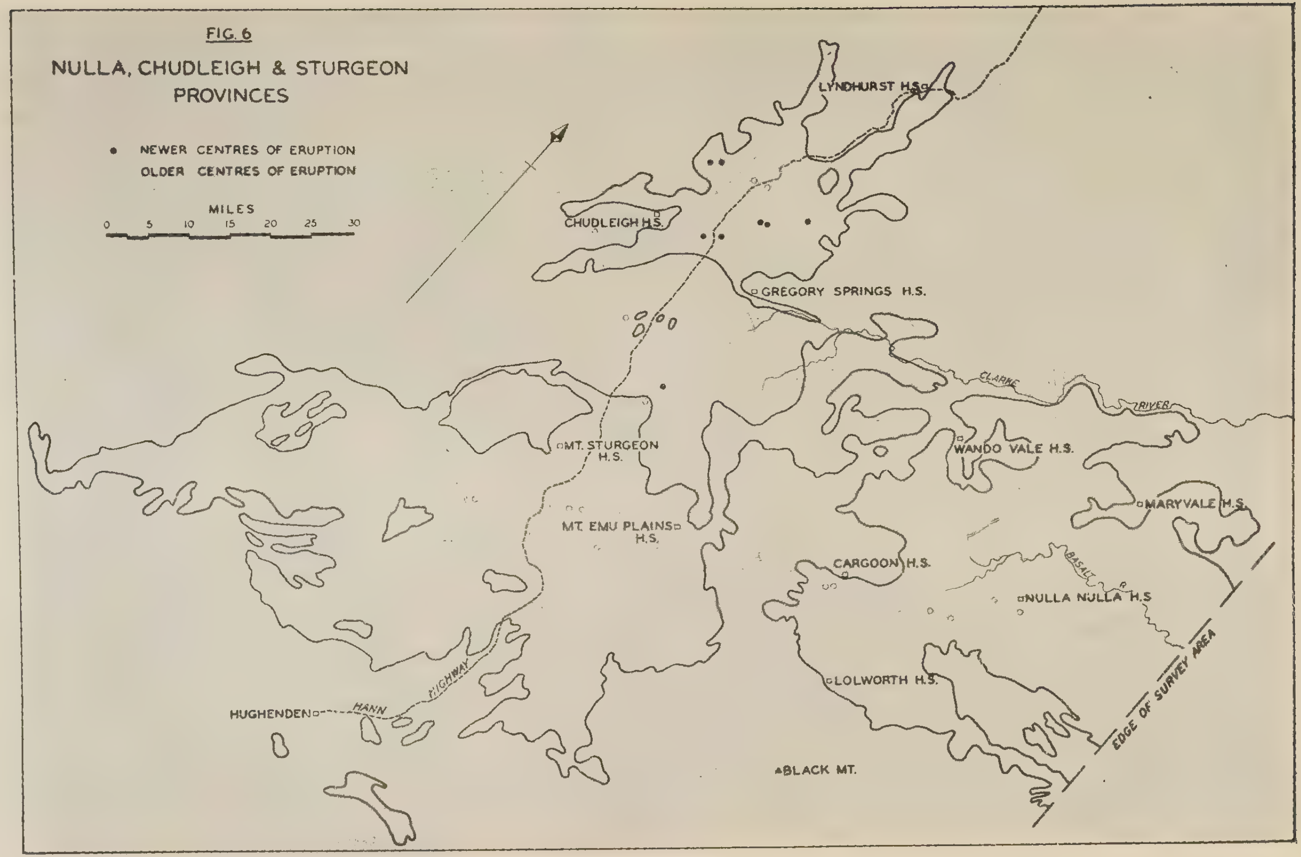


FIG. 6

NULLA, CHUDLEIGH & STURGEON PROVINCES

in the Nulla Province than in the northern area, and cones, or centres of eruption, are less frequently encountered - seven recognised centres [*] as opposed to over sixty in the McBride. These differences are thought to be due to a slightly greater age of the basalts as a whole.

C. - Chudleigh Province

This is the smallest province of the four with only 500 square miles total area and is unusual amongst the basaltic areas of the Leichhardt-Gilbert Area by virtue of the fact that it is essentially a valley flow and is bounded on three sides by high hilly country. On the fourth side the lava tongues down valleys eroded in Palaeozoic igneous and metamorphic rocks. A dozen centres of eruption, seven of quite recent age, have been located within this small area, and six of these, as can be observed in Fig. 6, clearly occur along a north-east - south-west trending line. Marginal drainage impedence is common in this province and the general landscape consists of low stony rise remnants with occasional scoriocones and lava cones breaking the general plain surface.

D. - Sturgeon Province

A vast amount of peripheral dissection characterises this volcanic province, which covers an area of approximately 2,400 square miles (see Fig. 6). The maximum dissection of the basalt sheets has been achieved where the underlying rock is a soft Cretaceous shale, a circumstance which facilitates undercutting. In general the landforms are similar to those described in the McBride Province, the flow-scarp features being especially prominent hereabouts. Again there is a general domelike form and once more the dome is demonstrably composed of successive lava flows. On Porcupine Creek, for example, about 6 miles south of the Whitecliff Gorge Crossing and 30 miles north-north-east of Hughenden, four structural benches related to successive lava flows can be observed.

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[*] It is, however, quite possible and even probable that other centres are present here and in the Sturgeon Province (see later) but have not been identified. In the Victorian basalt sheets there is at first sight a similar scarcity of eruptive centres, but with detailed topographic mapping numerous small low mounds, now becoming accepted as ancient foci, are apparent (HILLS, *personal communication*). The relevant point is that at the broad scale at which the survey reported here was conducted, an evident scarcity of eruptive centres does not of necessity imply fissure eruption.

Many of the gorges which have been excavated near the margins of the Province are over 200 feet deep; several contain excellent examples of ingrown meanders and there are high-level perched and abandoned meander cut-offs postulated to be of autogenic origin on Spring Lawn Creek, about 35 miles north-north-east of Hughenden (Twidale, 1955). In the south, many parts of the basalt plateau have been isolated by circumdenudation leaving basalt capped mesas and residuals such as Mts. Walker, Mowbray, Wongalee, Castor and Arthur standing above the plain level. In this southern area also the slumping of basalt on scarps is marked, and is due to undercutting by removal of underlying unresistant rocks. One feature which should be mentioned is an excellent example of an « alcove » (as named and described originally by Russell (1902) and later by Stearns (1936)) near Charlotte Plains, 35 miles north-west of Hughenden, where soft Cretaceous shales have been eroded or sapped by springs and the headward erosion of streams, with the result that the overlying basalt has been undermined.

Near Porcupine Gorge several levels of the basalt surface are present and this may be attributed either to faulting or to local stripping or planation of some of the basalt flows. In the basalt near Mt. Sturgeon Homestead many interesting features, including « toes », salamander structures and impressions of wood enfolded in the lava (see Plate V) can be seen.

Only nine centres of eruption, of which Mts. Emu, James, and Sturgeon are examples, have been identified within the whole of this province and all of these are of considerable antiquity, being well-weathered and much dissected.

Other isolated volcanic phenomena are known to occur within the Leichhardt-Gilbert Area, and especially in the Chudleigh-Cheviot districts, but one worthy of special mention is Black Mountain, a single basaltic plug situated 60 to 70 miles east-north-east of Hughenden (see Fig. 6).

III. Regional Contrasts

The major contrasts between the four provinces concern:

a) the amount of peripheral dissection,

b) the general progress of weathering,

c) the number and preservation of old volcanic foci.

Although the general topographic situation undoubtedly influences the effect of the first of these, its relative effect is somewhat unknown and age is the most important overall factor that is considered here.

A. - Relative ages

There can be little doubt that the two areas of quite unweathered and undissected basalt mentioned in previous pages and referred to as the Kinrara and Toomba basalts represent the most recent volcanic manifestations present in the Leichhardt-Gilbert Area. In these localities insufficient time has elapsed since the cooling and consolidation of the basalt for denudation to have had any observable effect.

Of greater antiquity is the McBride Province, omitting the Kinrara basalt already mentioned. The peripheries of this province are considerably dissected though not nearly as much as, for instance, the Sturgeon Province, and a large number of centres of eruption remain recognisable as such. Using the state of denudation of the cones as a criterion, at least two ages of foci (and basalts) are distinguished within the McBride Province (excluding the Kinrara basalt) and it is certain that a detailed study of the basalts (e.g. the extension of the feature illustrated in the Rosella Plains section, Fig. 3) will disclose several more. The older cones of the McBride area and the older cones of the Chudleigh Province are approximately comparable, as are also the newer cones of both areas and the two provinces are regarded as having had similar histories. There is represented within each province a minimum of two volcanic periods and basalts, which will be referred to as the Older and Newer McBride, and Older and Newer Chudleigh, and between which denudation occurred. Denudation of much longer duration occurred between the later vulcanicity of the McBride and Chudleigh Provinces and that related to the extrusion of the Kinrara and Toomba basalts.

The Sturgeon and Nulla Provinces are considered, from their evident dissection and weathering, to be older than both the Kinrara and Toomba basalts and the younger of the McBride and Chudleigh basalts, i.e. those related to the Newer McBride and Chudleigh periods. They may well have originated contemporaneously with the Older McBride and Chudleigh basalts.

In summary we may thus tabulate the basalts, and the landscapes associated with them:

Table I

3. Kinrara and Toomba.
2. Newer McBride and Newer Chudleigh.
1. Older McBride and Older Chudleigh.
   Sturgeon and Nulla.

This is merely a very broad and relative order, but is of interest in that a general south to north movement of vulcanicity is indicated in the geological time represented.

B. - Absolute ages

In those parts of north Queensland with which this paper is concerned, no fossiliferous deposits have been found overlying the basalts, but in all provinces the basalts are known to overlie lateritised rocks of Palaeozoic, Mesozoic, and early Tertiary (probably Eocene and/or Oligocene) age. It has to be recorded, however, that the ages of these lower Tertiary strata have not been palaeontologically determined.

WHITEHOUSE (1940) has stated that lateritisation occurred in north Queensland in late Miocene and early Pliocene times, but from a consideration of the surfaces of erosion of the area there is, in the opinion of the present writer, no reason why the lateritisation process could not have been in progress in much earlier Tertiary ages. The reasons for differing from the view of WHITEHOUSE are more fully explained elsewhere (TWIDALE, forthcoming publications) but may be reviewed for the purposes of the present paper as follows.

Upon a surface of erosion resulting from the dissection and planation of the uplifted lateritic plain, sediments, some of which are of certain Pleistocene age, and others of probable Pliocene age, were deposited. The erosion of the surface — which is one of low relief — on which the sediments lie must therefore be pre-Pliocene and the inception of the post-laterite cycle of erosion, by uplift and warping, surely cannot be placed later than the Miocene age. The period of lateritisation must therefore occupy Miocene and earlier times and this writer thinks of it as occurring in the early and mid Tertiary periods. Such a dating is in accord with that postulated by KING (1949, 1950).

Whenever the extrusion of basalts occurred over a lateritised surface, that profile would be preserved as such. There is no reason why the lateritisation period should have terminated prior to the vulcanicity, but no sign of the lateritisation of any basalt has been seen in the area in question, nor has any sign of pre-basaltic erosion of the lateritised surface been observed. Furthermore, to the north-west of Hughenden, near Charlotte Plains, non-lateritised gravels have been observed to overlie Mesozoic rocks and underlie the basalts: no palaeontological evidence of the age of the gravels is available, but from their general unconsolidated and unlateritised nature they are not considered to be older than late Tertiary.

In the face of this varied but admittedly indefinite evidence, the writer opines that the earliest period of vulcanicity does not go back beyond the late Tertiary.

A rather different, subjective, comparative approach can be made comparing the state of weathering and dissection of the basalt provinces in this area with other volcanic provinces. The present writer gladly acknowledges the assistance that has been given by Professor E. S. Hills, University of Melbourne, who, accompanied by the author, briefly toured parts of most of these volcanic areas in the Leichhardt-Gilbert Area. Hills considers that the preservation of such original surface features of the basalt surface as « stony rises » suggests a relatively recent age, but gives more weight to the considerable dissection that has occurred, especially in the southern provinces, and does not think that the most ancient (i.e. Sturgeon) province can be any younger than late Pliocene or early Pleistocene.

If, as has been suggested earlier, the age of the basalts does, generally speaking, decrease to the north, then the following table may be proposed:

Table II

RECENT		
	Kinrara and Toomba basalts	late Pleistocene to early Recent
PLEISTOCENE	Newer McBride and Newer Chudleigh basalts	early to mid Pleistocene
	Older McBride and Older Chudleigh, Sturgeon and Nulla basalts	late Pliocene to early Pleistocene
PLIOCENE		

IV. Nature of the Vulcanicity

The main purpose of this paper has been to discuss the physiography of certain basalt areas in north Queensland but it is nevertheless both necessary and desirable to briefly discuss the nature of the vulcanicity to which the basalt plains and plateaux are due.

Jaggar (*loc. cit.* p. 200) regards cones and domes as superficial and inadequate, vents and fissures as profound, and he, almost certainly, would not consider even the sixty centres of eruption discovered in the 2,400 square miles of the McBride Province (the province with the maximum number of cones per unit area of basalt outcrop) to be sufficient to account for the large spread of lava, and would find it necessary to postulate the presence of fissures unless, as most vulcanologists do not, it is supposed that mobile plastic matter is situated immediately beneath volcanoes.

However, it must be noted that STEARNS and CLARK (1930) attribute the basalts of the Hawaiian area, which is the area which JAGGAR studied, to shifting vents of the shield type, i.e. a central type of eruption.

TYRRELL (1937, pp. 92-95) has classified (Epeirogenic) basalts into three types, viz:

a) Multiple-vent basalts.
b) Shield basalts.
c) Flood basalts.

In the paper cited, TYRRELL was mainly concerned with the last type mentioned, but it is clear that on his criteria the basalts of north Queensland fall into the « multiple-vent » category. He describes them as « accumulations arising from the confluence of lava flows from a large number of small and closely spaced volcanoes. The flows coalesce into masses of the order of size of a few hundreds to a few thousands of square miles... » (*Ibid.* p. 92). GREGORY (1929) and RECK (1930) have used the terms « plateau basalts » and « areal eruption » respectively for phenomena similar to the multiple-vent type of TYRRELL, who, however, rejects the previous nomenclature as ambiguous and inadequate: in this paper the terminology proposed by TYRRELL is utilised.

The Carboniferous basaltic region of the Clyde (Scotland) area, in which over 2,000 square miles of basalt were erupted from over 70 small volcanoes, is mentioned as a fine example of the multiple-vent type (TYRRELL, *loc. cit.* pp. 92-93). The comparison between it and the McBride Province is striking.

A further indication that these north Queensland basalts are related to a central type of eruption and not to fissures is to be found in the doming of the basalt districts, a feature particularly marked in the McBride Province. Hypomagmatic intrusions are strictly comparable with laccolithic intrusions, e.g. of granite, and it is only when the superincumbent edifice or roof yields that volcanic phenomena result from the relief of pressures and the conversion of hypomagma to pyromagma. The accumulation of magma as sills and laccoliths within such great domes as Mauna Loa is suspected as the cause of observed upswellings of this and other volcanoes, (JAGGAR, 1931, p. 2, *vide* COTTON, 1952, p. 13). Although sinking may follow from the drawing off of such magma, it is worthwhile deliberating as to whether the dome of the McBride district may not be in part at least due to such magmatic intrusions, though it is recognised that the accumulation of successive lava flows must be at least a contributary cause of this phenomenon. The detailed mapping of the individual flows would be enlightening in this respect.

The absence of any marked trend in the distribution of the cones also supports the central type theory, but this matter of central *versus* fissure eruption cannot be determined definitely until the plateaux have undergone considerable deep dissection. Both schools of thought may be correct in given areas, and all that can be stated at present is that the indications in the north Queensland area favour the hypothesis that the basalts are the multiple-vent type, and thus that they are related to a central type of eruption.

V. Summary and Conclusions

1. The physiography of four distinct basalt provinces, which occur in north Queensland, is described.

2. The provinces, which consist overwhelmingly of olivine basalt, have been mapped as has also the distribution of volcanic cones or former centres of eruption.

3. The basalts are ascribed to at least three periods of vulcanicity which were separated by considerable periods of weathering and erosion, and which are tentatively considered to be of late Pleistocene or early Recent, early to mid Pleistocene, and late Pliocene to early Pleistocene age; a south to north movement of vulcanicity is indicated.

4. The basalts are thought to be of the central « multiple-vent » type of TYRRELL.

5. The paper is the result of a brief reconnaissance survey and this account can only be considered a beginning; it is hoped that the mention accorded to some of the problems of the provinces will lead to their subsequent detailed investigation.

VI. Acknowledgments

The writer wishes to thank Mr. J. N. Jennings of the Australian National University, Canberra, and colleagues of the Land Research and Regional Survey Section of C.S.I.R.O., Canberra, for their help and encouragement in the preparation of this paper.

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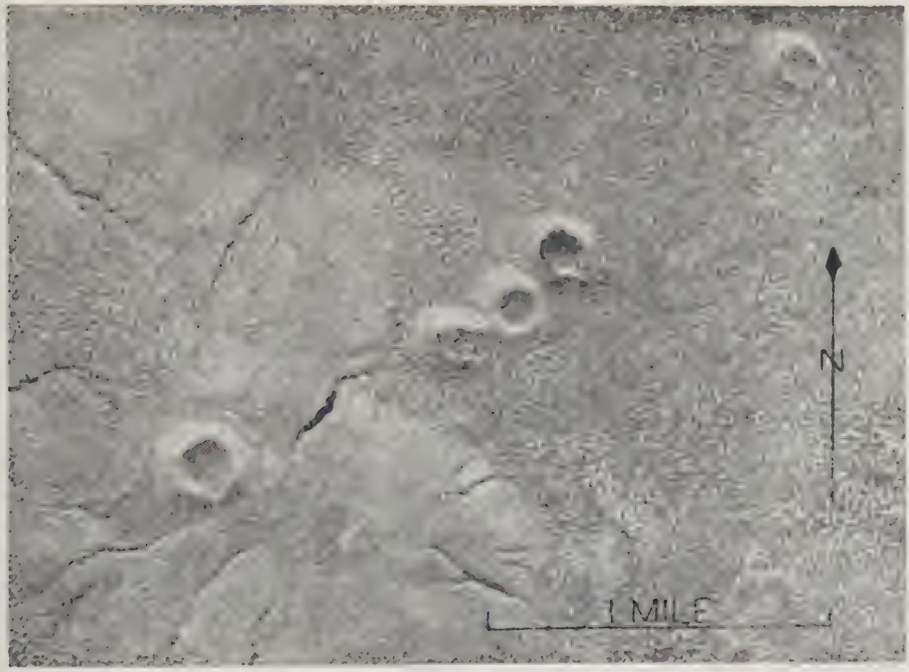
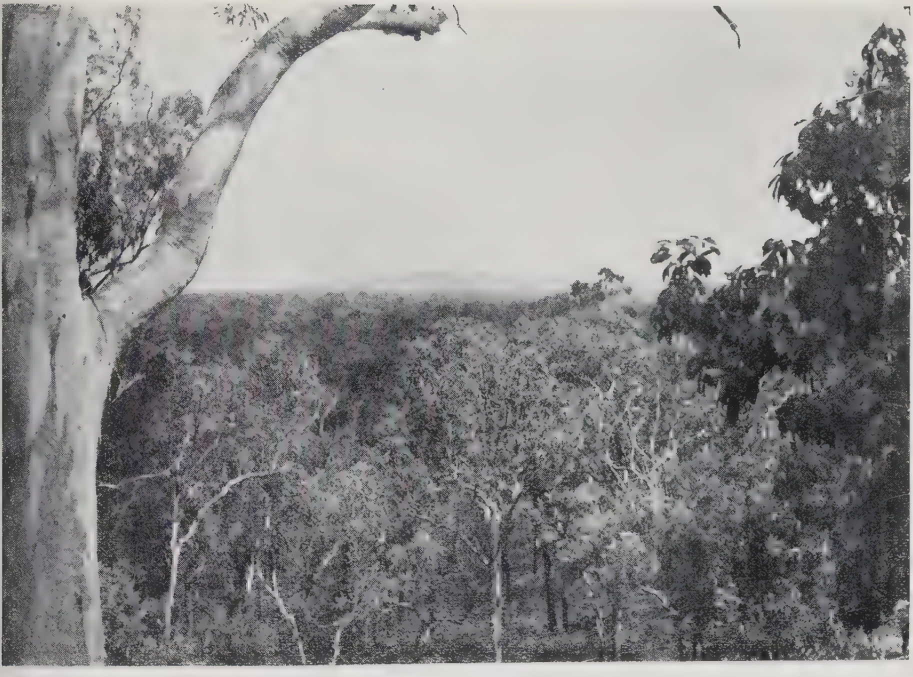
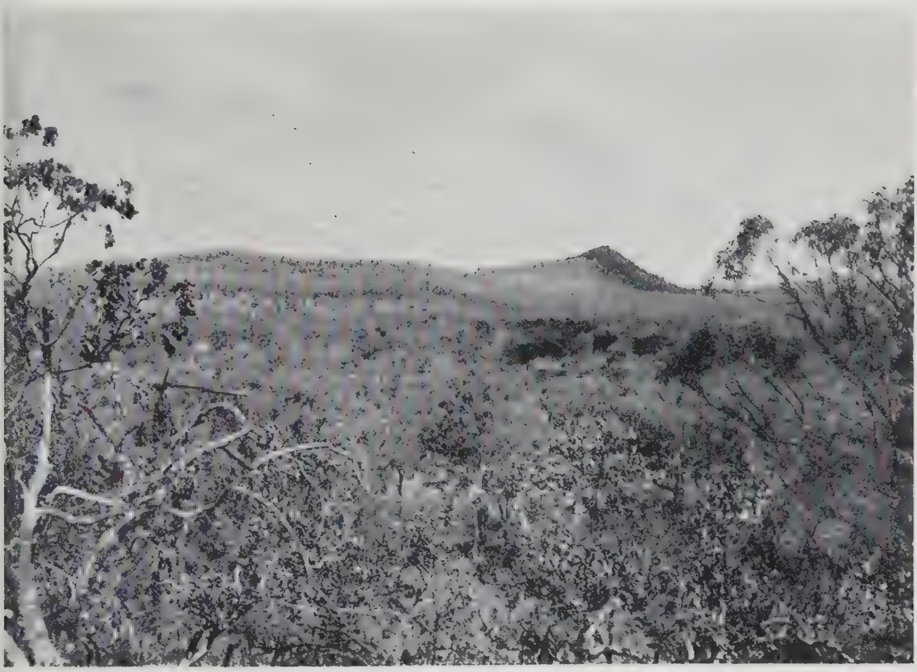


(Reproduced by permission of the R.A.A.F.)

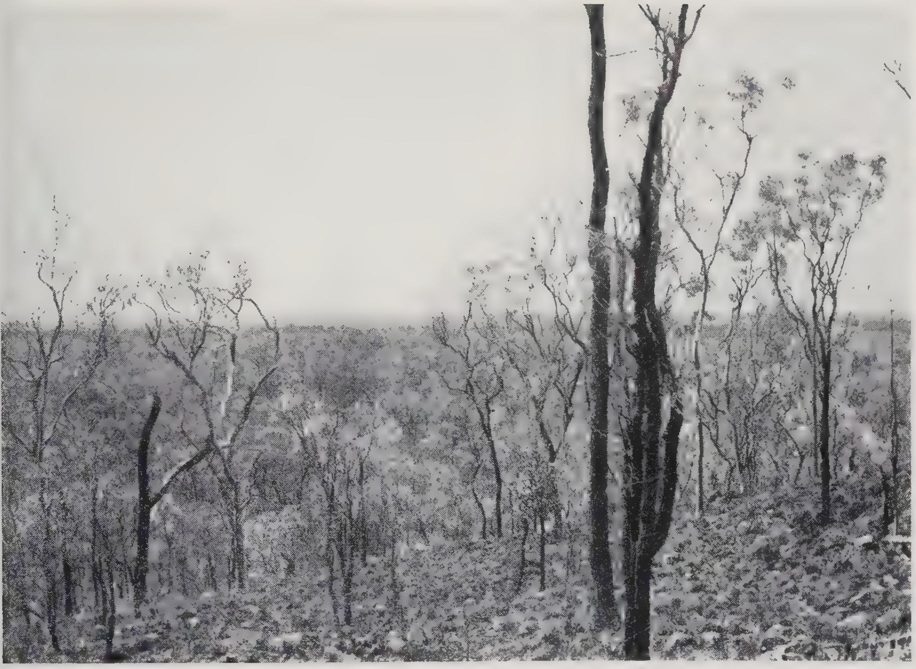
Aerial photograph of Mt. Tabletop, near Rosella Plains in the McBride Province. The main cone is of the Mauna Loa type while four adventive cones are located on the north-eastern flank; yet another structure occurs to the south-east of the main vent



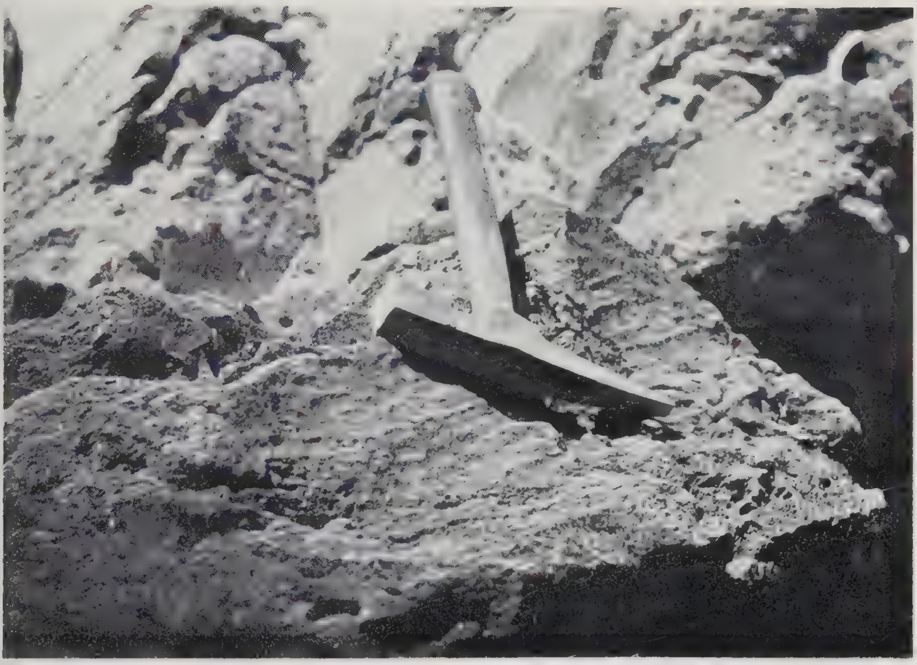
Mt. Tabletop from the south-east. The main vent and three of the adventive cones are clearly discernible.



Low basaltic cone with central crater viewed from the north. The feature is located near the Hann Highway, some 25 miles north of Conjuboy Homestead, and the crater rim is especially prominent on the western side.



Mt. McBride, a basaltic scoriocone, viewed from the north-west, from the cone shown in Plate III.



Wood impressions in basalt found near Mt. Sturgeon Homestead, some 45 miles north of Hughenden.

G. A. TAYLOR

Australian National Committee on Geodesy and Geophysics

Report of the sub-committee on Vulcanology, 1953

Review of Volcanic activity in the territory of Papua-New Guinea, the Solomon and New Hebrides Islands, 1951 - 53

(With 8 figures)

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Papua - New Guinea

Rabaul

Some progress has been made in the re-establishment of the vulcanological observatory since 1951. The observatory building has been completed and instrumental equipment now includes Benioff seismometers and tiltmeters. As officer in charge of the observatory Mr. J. G. Best has supervised the reconstruction work and installations.

In addition to systematic observation af the Rabaul craters, the observatory is kept informed of seismic and volcanic activity throughout New Guinea- Papua and the New Hebrides by a system of special report forms which have been distributed to local observers throughout these regions. Since the writer's visit to the New Hebrides in 1951 information from that area has been obtained by courtesy of Mr. W. B. Roberts who, in the capacity of honorary vulcanological observer, has arranged a system of local observers for the group and carried out a number of valuable inspections of active centres.

Investigations of increased volcanic activity at a number of outlying centres has been carried out during the last three years.

Mount Lamington

The explosive phase of this Pelean type volcano lasted five months. It ended in June, 1951. The subsequent effusive dome-building phase was characteristically long-continued and declined slowly. During 1952 the dome reached a maximun height of approximately 1900 feet above the old crater floor and further increase in the overall mass of this structure has since taken place. Dome movement was still perceptibile during the latter part of 1953.

Gas emanations correspondingly declined during this period but there were fluctuations in volume from time to time.

The seismic activity had fallen to negligible proportions by the end of 1952 when the vulcanological station was temporarily disbanded pending the arrival of equipment for permanent seismic observations in this area.

Submarine Activity

On 24th November 1951 Captain Mellor of the vessel « Tarra » reported a marine disturbance in a position 21 miles east-north-east of Karkar Island. A boiling, turgid expanse of

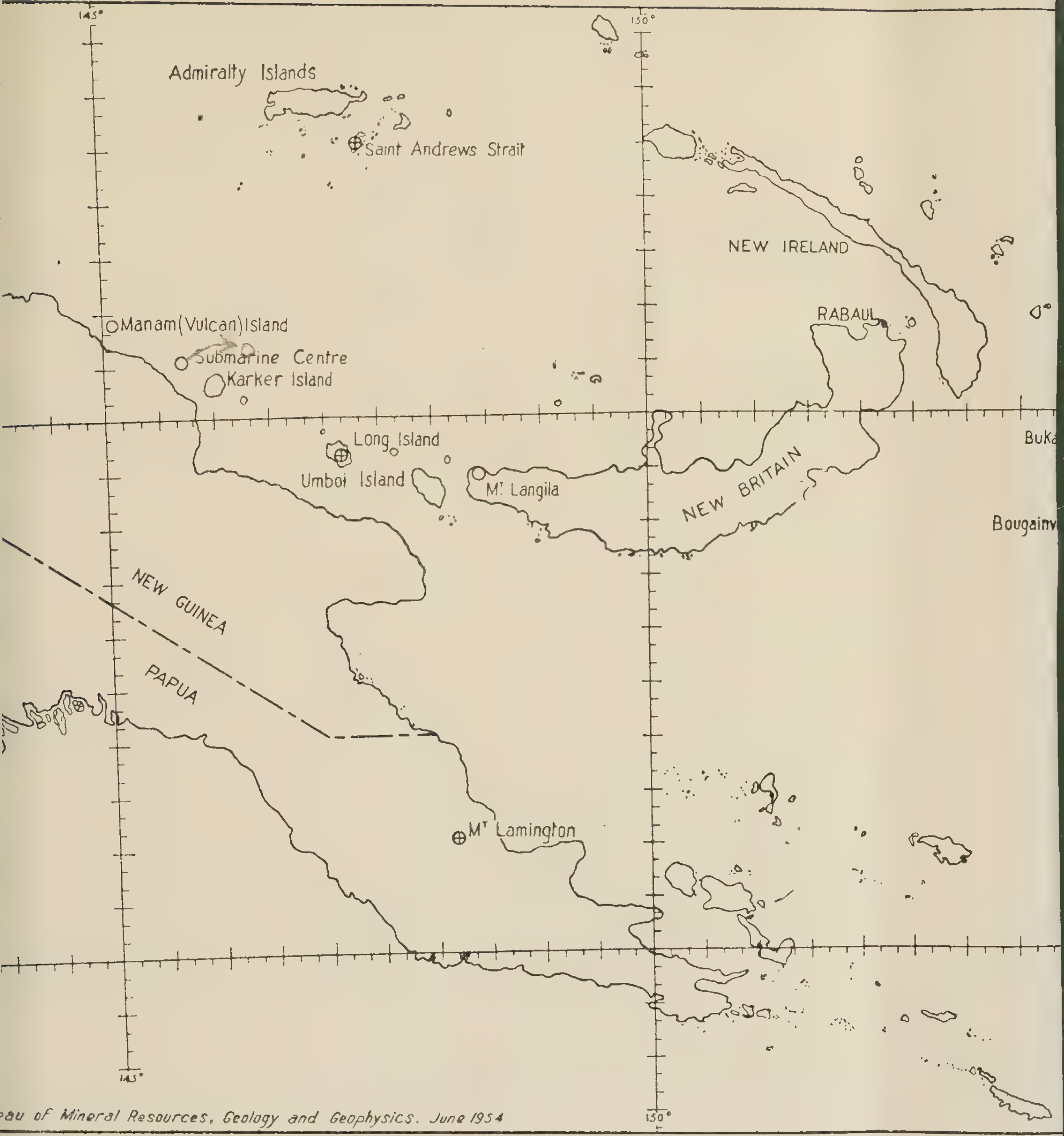

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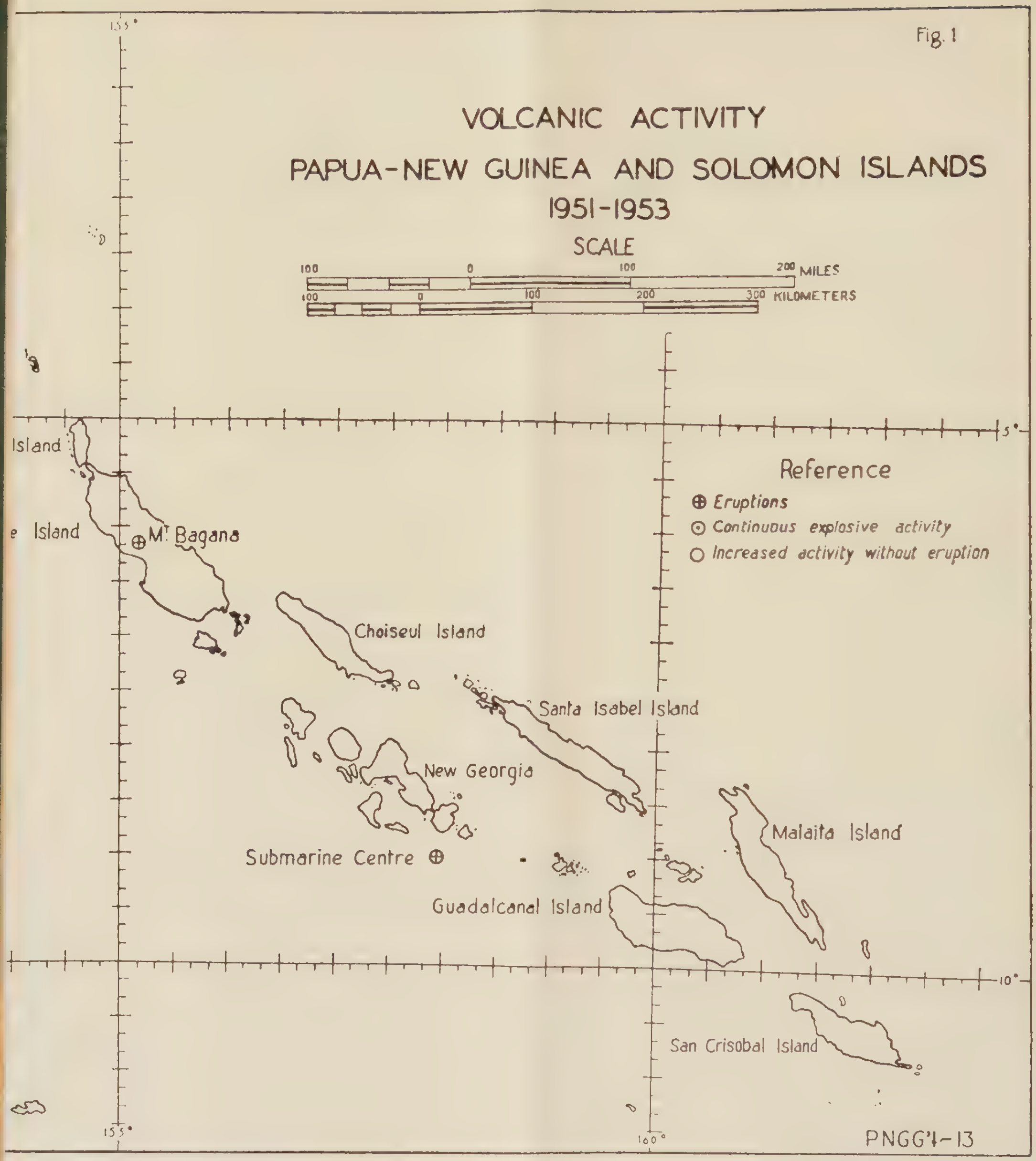
Fig. 1. - Map of New Guinea and Solomon Islands s



owing centres of volcanic activity 1951-53.

sea covered an area with a perimeter of about 3 miles. Dead fish and marine growth were thrown up.

This was the first of a series of events which suggested the possibility of a regional pattern of reactivation.

Mount Langila

Increased activity of this volcano was investigated by TAYLOR and BEST in the latter part of 1952. Vents in an old crater, which had been inactive when inspected by FISHER in 1939, were emitting high pressure gas at temperatures up to 240°C. The gas contained high concentrations of SO_2 and SO_3 and destroyed the forest on the leeward slopes of the mountain for a distance of a mile and a half. An analysis of one of the condensates collected from the vents gave the following composition:

Suspended Matter	Milligrams per litre
Colloidal sulphur	4,386
Dissolved Matter	
Reaction	strongly acid
Total acidity (in terms of normality)	0.926 N.
Calculated as H_2SO_4	45,374
» » HCl	33,764
Total Residue on Evaporation	22,000
Sodium	present
Potassium	trace
Calcium	32
Magnesium	13
Iron (ferrous)	17
Selenium	not detected
Arsenic	1.5
Chlorides	
as Cl	14,457
as HCl	14,457
Carbon dioxide	not detected
Sulphides (and H_2S)	absent

Sulphur oxyacids	
Sulphurous acid	
Calculated as SO_2	7,306
» » H_2SO_3	9,349
» » S	3,653
Sulphuric acid	
Calculated as SO_3	9,425
» » H_2SO_4	11,533
» » S	3,770
Polythionic Acids	
Calculated as S	5,311
Fluorine	trace
Boric acid	trace

Deepseated rumbling was noticed during July and August while the party was encamped on the upper slopes. The low-pitched rumbles were short and usually accompanied by a brief short-period ground movement which, on one occasion, included vertical bumping. No appreciable change in crater conditions accompanied these noises.

In October further observations revealed a slight fall in temperatures but no appreciable change in gas emission. A tiltmeter installed near the summit of the cone showed a variation of 8 minutes over a period of several days. Also, for prolonged periods, bubble movement indicated the existence of persistent long-period groundwaves.

Readings taken at other locations, within 30 miles of the volcano, suggested that the focus for this crustal disturbance was centred on the nearby Umboi (Rooke) Island where a severe earthquake with very numerous and persistent aftershocks had occurred.

The next premonitory symptom of possible volcanic instability was reported from Manam island, 250 miles west of Langila.

Manam Island

J. G. Best (1954) examined this volcano in April and August 1953 following reports of increased gas emission and luminous effects from the crater. The last eruption from this centre had taken place in 1946-1947, when explosive activity spread dust and lapilli over most of the island and a blocky lava flow descended from the south-east side of the cone to reach the sea between the villages of Dugulava and Warisi.

Ascending the slopes of the terminal cone, which were covered with loose ash, scoria and lapilli, Best reached the summit. He found two adjoining craters which were breached on the eastern side. Each crater contained one major active vent and secondary areas of hot ground. He reported (1954) « The vapour cloud rising from the northern fumarole is emitted without audible effects and billows up effectively blanketing the greater portion of the crater ». On the other hand, he observed that « the southern vent is much more active, explosions from within the vent at fairly regular intervals (half minute to one minute) shake the crest and hurl swirling clouds of vapour high in the air ». Quite appreciable amounts of sulphur dioxide were present in the gas cloud.

Problems of accessibility prevented temperature measurements.

Long Island

When examined by Fisher (1939) and by Best and Taylor in August 1952 no signs of volcanic activity were evident. The small cone, near the southern end of the caldera lake, which was evident on air photos of 1943, was not visible in 1952.

On 8th May 1953 a column of smoke was seen rising from the island. When examined by aircraft the following day a horseshoe shaped ridge had been built up above the lake level by the products of explosive activity which was taking place. Best reports that on the 12th May jets of black ash and steam were being thrown up by explosion at 15 to

20 second intervals. Within 4 or 5 days a cone standing 100 feet high and about 200 yards long had been formed above lake level.

A night inspection by R.A.A.F. aircraft on 14th May reported explosive ejection of incandescent material at 15 second intervals. A second vent had opened up to the north-west of the cone by the 19th of May and when inspected on 23rd May the dimensions of the ridge-like cone were approximately 400 yards by 100 yards and 100 feet high.

The crater was inactive when examined on 12th June. Spasmodic activity continued, however, during the following months. The last outburst was reported on 7th January, 1954.

Saint Andrew Strait

The only earlier report of volcanic activity in the Admiralty Group refers to an eruption in the vicinity of Lou Island in 1883. No details are given.

At 11 p.m. 27th June 1953 a submarine explosion produced a column of vapour which emerged from the sea between the islands of Baluan and Lou. The associated disturbance of the sea did some minor damage on the adjacent island of Pam Mindian. On the morning of June 25th a vapour cloud stood 2000 feet above the area, and subsequent activity consisted of explosions at irregular intervals which « hurled jets of black ash and lapilli several hundreds of feet in the air » (Best, 1954). Large blocks of floating pumice littered the sea around the active area.

At night a glow could be seen over the area and intensification of the glow preceded explosions.

Seismic activity associated with this eruption was of a minor order and scarcely perceptible on the surrounding islands. A correlation between slight shocks and explosive activity was noticed by Best during the course of the eruptions.

This first period of activity had ceased by 6th July. Further explosions occurred during the ensuing months. The last activity was reported on 18th February, 1954.

Mt. Bagana

With its viscous lava flows, dome-plugged crater and frequent spasmodic explosive activity, which often produces glowing clouds, the characteristics of this volcano recall those of Java's Merapi.

First examined by the writer in Dec. 1950, a few weeks after a particularly powerful explosive phase, Bagana's activity was confined to the emission of high temperature gas, extremely slow movement of a lava flow on the south-southwestern flank, and loud, deep-seated rumbles every few days. The forest on the southern side of the volcano had been flattened by the passage of a recent nuée for a distance of about 2 miles from the base of the mountain. The fallen tree trunks were orientated radially with regard to the crater, and the bark of standing stumps was bruised and pitted on the side facing the crater, but charring effects were not observed.

On 29th February 1952 explosions from Bagana were reported to be sending ash clouds to 20,000 feet. Best found the eruption still in progress when he visited the area late in April, and during a brief period of observation of little more than a week he observed several glowing clouds which were probably of the type « nuées ardentes d'explosions vulcaniennes ». Samples of ash from one of these nuées were still at incandescent temperatures when collected about an hour after deposition.

Daily explosions were reported at the end of June 1952.

In June 1953 the volcano was particularly noisy with loud roaring and rumbling. A new crater, reported to have formed on the northern slopes, produced a series of powerful explosions. At night the lava flows moving down the slopes glowed brightly. Frequent earthquakes were associated with this activity. During July and August more powerful explosions with high dust clouds were reported.

Petrological examination of the lava from the 1950 flow suggests a more basic composition than the flow material examined by Baker (1949). The zoned plagioclase constitutes 65 % of the phenocrysts in the brown glass groundmass and the composition is that of a bytownite. Olivine percentages ranged from one to two and the magnetite, pyroxene and hornblende constitute about 30 % of the phenocrysts in this porphyritic lava.

Solomon Islands

J. C. Grover (1954), Senior Geologist of the British Solomon Islands, reports that intermittent submarine activity has been going on at one centre for some years. It is situated south of Vangunu Island in the New Georgia Group, Latitude 09° 01′ South, Longitude 157° 57′ East.

Numerous native stories of « fire on the water » in late 1950 were unconfirmed until one night, 15/16th April, 1952, the MV « BILIKI » sailed through a disturbed area of sea about a quarter of a mile diameter and narrowly missed being engulfed in columns of water and incandescent material which were being thrown up by submarine explosions. In May and June explosions with heavy detonations and roaring were taking place.

« The natives at Penjuku Village (at the extreme south-eastern end of the picturesque Maroro Lagoon) frequently observe the phenomenon. Sometimes it takes the form of a dome-shaped column of water, sometimes a column of greater height, and frequently rising « mushroom » cloud of smoke. These latter are accompanied by most violent detonations and sometimes by earth tremors.

In late 1951 small tsunamis occurred frequently, but these have not occurred since ».

Grover makes the interesting observation that native divers were unable to operate off the coast of an island twenty miles from the centre owing to the painful concussive effects on the ear drums caused by the submarine explosions.

On 11th November, 1952, the tip of the cone showed above the sea in the shape of a welded pile of angular blocks 100 feet long, 20 feet wide, and about 15 feet high. By December the island stood 100 feet high and frequent explosions were ejecting incandescent material. The island had disap-

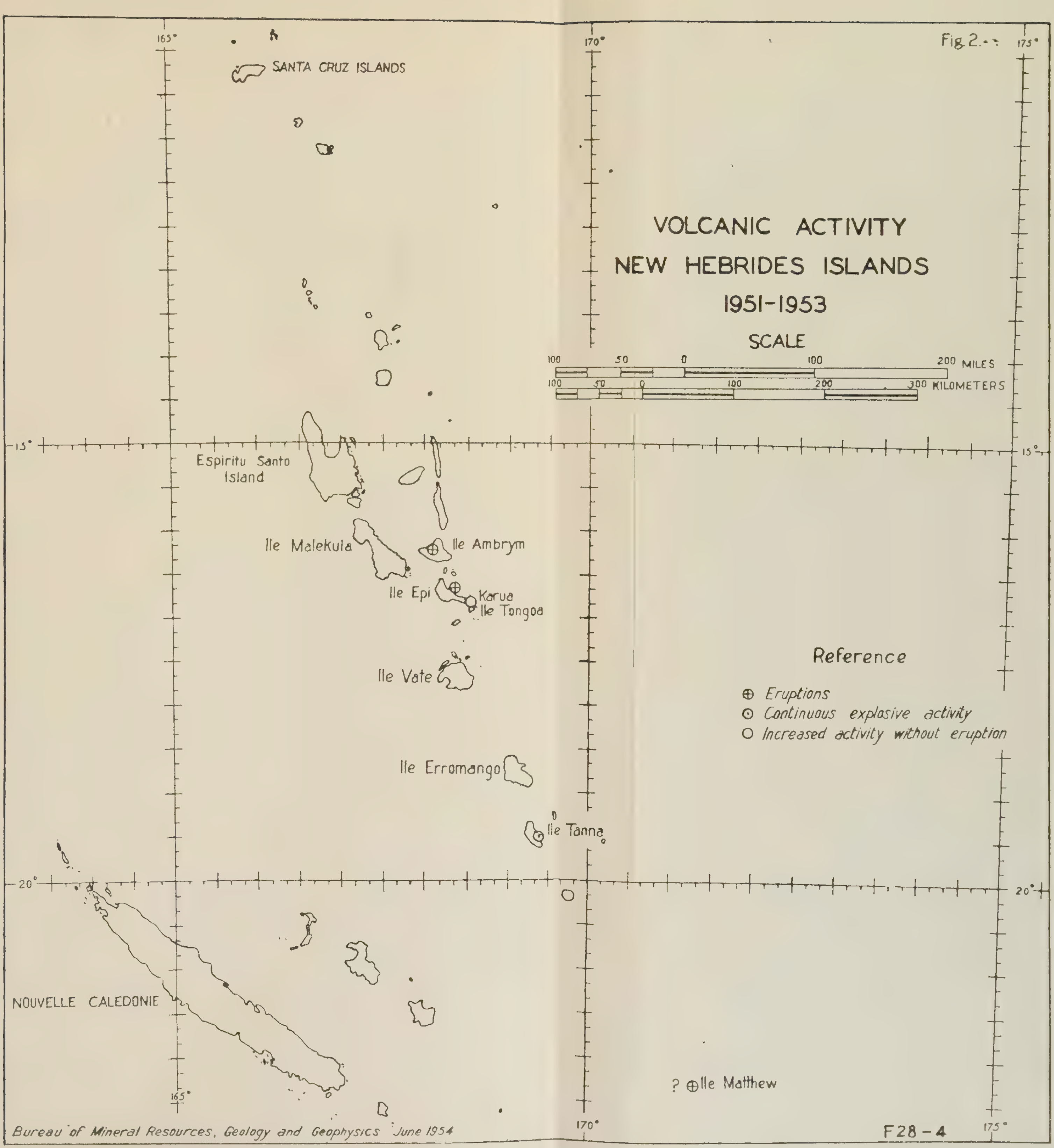


Fig. 2. - Map of New Hebrides Islands showing centres of volcanic activity 1951-53.

peared by 19th January, 1953, but explosions were occurring at two-minute intervals. The next day when circling the area by aeroplane Grover saw explosions lift « a white column of water about 400 yards in diameter to a height of several hundred feet. Sea waves 40 to 50 feet high were initiated and rolled out across the Pacific in everwidening circles ».

During the latter months of 1952 the powerful explosive activity which built the cone above sea level coincided with reports of an unusual number of earthquakes in the western islands of the group.

New Hebrides

Ambrym

Over the last 60 years this volcano appears to have produced a climactic eruption at intervals averaging about 12 years.

When the writer examined it in Nov. 1951, powerful explosive activity had been taking place over the previous eleven months. Ash deposits on the southern margins of the islands were not less than a foot deep and in the vicinity of the crater the depth of the ash was well in excess of 30 feet. Practically all the native population in the south had moved to the neighbouring islands of Epi and Malekula. The influence of the prevailing winds on the distribution of ejecta had limited the area of severe devastation to the southern portion of the island.

The activity had originated from the crater Benbow, which is situated on the south-western rim of the ancient caldera plateau occupying the centre of the island. Unlike earlier eruptions no lava flows were associated with the activity and no external vents were involved. Ejecta consisted of a highly vesicular black scoria which ranged in size from blocks a foot in diameter to sand. Much of the material had a glassy surface and an iridescent sheen as evidence of its molten state at the time of ejection.

The ash from the eruption had the following composition:

	Percentage by weight
SiO_2	49.60
Al_2O_3	17.20
Fe_2O_3	3.97
FeO	7.85
MgO	4.98
CaO	10.12
Na_2O	2.24
K_2O	1.66
MnO	0.37
TiO_2	1.00
P_2O_5	0.40
H_2O —	nil
H_2O +	nil
Cl	trace
SO_3	nil
S (sulphide)	traces
S (total)	0.06
CO_2	nil
carbides	traces

Compared with an analysis of the lava from the 1913 eruption there is little variation in composition.

The vesicular scoria consisted of a light brown-green glass (R.I. = 1.587) which contained angular inclusions of black glass (R.I. = 1.595). It contained phenocrysts of plagioclase, green augite, olivine, and magnetite. The plagioclase had a composition A_{n48-53}, compared with the labradorite composition of earlier ejecta.

The records of an observer on the neighbouring island of Paama suggested that the unusually prolonged and powerful eruption of Ambrym was accompanied by abnormal seismic activity. Investigation of this relationship has brought to light a very interesting correlation which will be described in a forthcoming paper.

After 9 months quiescence Ambrym resumed its explosive activity on 10th Aug. 1952. Intermittent activity ensued. The dust falls during this period were so heavy that by November the production from coconut plantations on the neighbouring island of Malekula were reported to be severely affected.

A marked increase in activity occurred again in May 1953 when a parasitic cone on the north east flank of Marum crater also became active and, later, a vent opened up on the southern side of Benbow.

ROBERTS made an ascent of Benbow in May and reported the presence of liquid lava in the crater. This was the first evidence of its presence in the crater since the climactic activity of 1951, and it suggests that the dust ejections of the previous months were due to the lava column rising through the debris-filled conduit that had been choked by material from the crateral collapse which followed the climactic explosions.

Karua

Karua is situated between the islands of Tongoa and Epi. It was named after submarine explosive activity in 1948 and 1949 had formed an island in this locality. Earlier history reports the formation of a similar island here in 1897 (MAWSON, 1905).

The activity of 1948 formed a low island which was eroded away during the south-east monsoon. More severe explosive activity in October 1949 built up a cone of fragmental material one mile in diameter and 300 feet high. This activity died out in December 1949. Once again marine erosion attacked the cone and by December 1950 it had disappeared.

On October 3rd 1952 several light explosions were reported, but the cone was not built above sea level on this occasion.

Submarine Eruption near Epi Island

On 10th February 1952 a previously unknown submarine centre erupted off the coast of Epi (16° 41′ S, 168° 22′ E). The disturbance was spread over an area of about a quarter of a square mile. Explosions threw pumice and ash hundreds of feet in the air and a glow was seen over the area at night. The explosive activity ceased on 17th February. About 400 square miles of ocean were then covered with a pumice « raft ». Boats could not pass between Lamen and Epi islands.

Soundings taken before this activity revealed a prominence which stood 40 fathoms above the surrounding 120-fathom sea-floor.

Mr. W. B. Dallwitz calls the pumice an olivine-bearing andesite. It is composed of glass containing phenocrysts of plagioclase, pale yellow-green augite, black iron ore and rare olivine. The plagioclase shows extreme oscillatory zoning and has the approximate composition of labradorite.

Matthew Island

On 8th October 1953 a passing ship sighted a new land mass beside Matthew Island.

Investigated by the French naval vessel TIARE on 30th October, this new land mass was reported to consist of a basaltic rock which was still warm, 465 feet high and between 400 and 500 yards in diameter, it was situated to the west of Matthew Island and connected with it by an isthmus of sand 20 yards wide.

A small crater, from which a lava flow had descended, was situated on the north-western side of the « cone ». Mildly active vents in the crater were emitting white vapour, and traces of sulphur were observed in the vicinity.

Yasour

On Tanna Island, this volcano produces a mild strombolian type of activity which has been described by E. Aubert de la Rüe (1937).

Mr. Bannister who has lived within two miles of the crater for some 20 years says that there has been no marked change in activity during his period of residence. When examined by the writer in December 1951 explosions were occurring at the rate of 30 per hour.

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PLATES

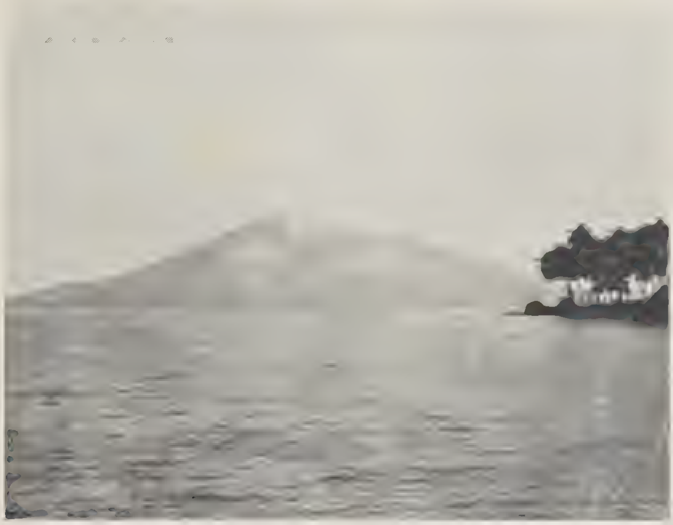

Fig. 3. - Activity from the two main vents of Manam Volcano.

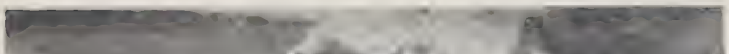

Fig. 4. - Explosions from cone raised in the caldera lake of Long Island Volcano.

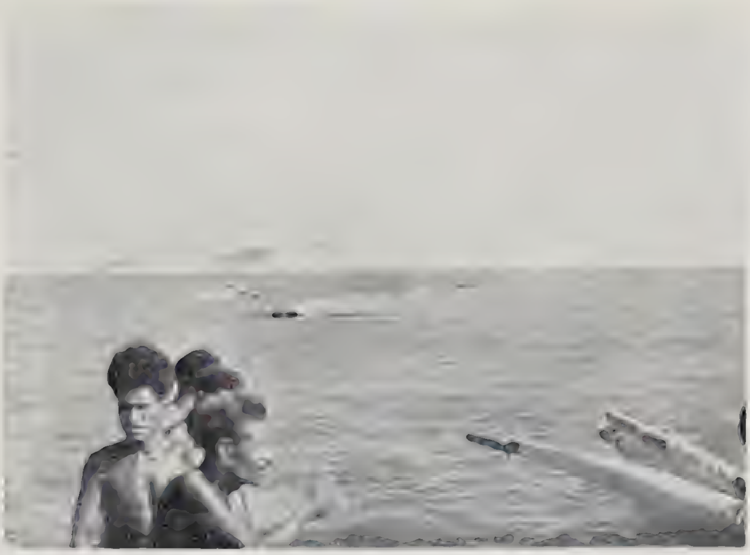

Fig. 5. - Steaming blocks of pumice floating in the sea around the active area in Saint Andrew Strait.

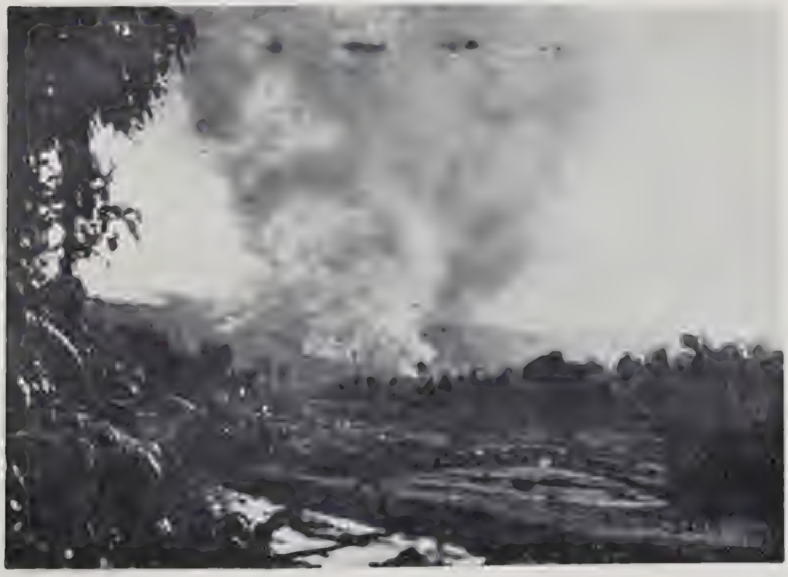

Fig. 6. - A nuée descending the slopes of Bagana Volcano.

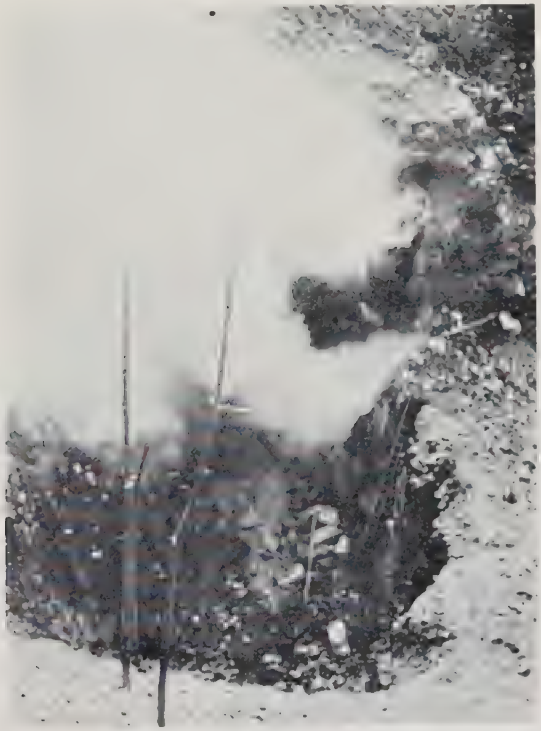

Fig. 7. - A 40 feet access ladder to the vents on the floor of Langila Crater

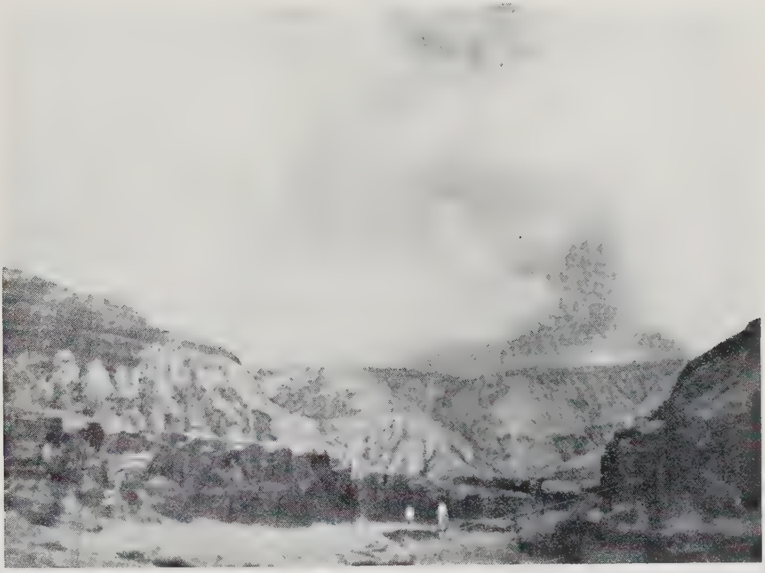

Fig. 8. - Approaching Benbow Crater of Ambrym Volcano through the mudflow valleys in the new ash

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Report on Volcanic Activities and Volcanological Studies in Japan for the Period from 1951 to 1954

(With 13 text-figures and 10 plates)

1. - Introduction

The volcanic activities in Japan during the period from 1951 to 1954 and volcanological studies concerning them are summarized in a condensed form in this report.

The following volcanoes manifested activity in the period in question, though their magnitudes of eruption were remarkably variable: Oo-sima, Myozin-syo (a submarine volcano), Asama, Aso, Suwanose etc. Of these volcanoes, the eruption of Myozin-syo was the most marked event in this period not only for its scale but also for the catastrophe caused. The 1953-1954 eruptions of Oo-sima were not so remarkable when compared with the 1950-1951 eruptions. Although Volcano Asama broke out very frequently from December 27, 1953, each of these eruptions was of extremely small intensity with ejection of volcanic ash and lava fragments of small size. This is in striking contrast to the usual Vulcanian eruption of furious intensity of this volcano.

This brief report is compiled by the writers on the basis of the papers and lectures conducted by volcanologists of various institutes including Tokyo University, other universities, Central Meteorological Observatory and Hydrographic Office etc.

The geographical positions of these volcanoes are represented in the map of Fig. 1 and Table 1.

Table 1. - Geographical positions of the active volcanoes in the period from 1951 to 1954.

No.	Name	Latitude	Longitude
1	Myozin-syo or Myojin-sho	31° 57′ N	140° 01′ E
2	Oo-sima	34° 45′ N	139° 23′ E
3	Suwanose	29° 38′ N	129° 45′ E
4	Aso	32° 53′ N	131° 08′ E
5	Yakedake	36° 13′ N	137° 33′ E
6	Asama	36° 23′ N	138° 28′ E
7	Akan	43° 22′ N	144° 02′ E

2. - Submarine Volcano Myozin-syo (Myojin-sho) 1) - 19)

1) The 1952 - 1953 eruptions of the Myozin-syo

On September 17, 1952, at 8 h (L.S.T.), a telegram from a fishing boat « Myozin-maru No. 11 » on the Pacific coast, 420 km S of Tokyo, informed us that a submarine eruption took place at the position NNE, 30 km of the Bayonnaise rocks. Afterwards, this submarine volcano was named « Myozin-reef volcano, or Myozin-syo, or Myozin submarine volcano after the discoverer, the fishing boat.

As soon as this report was received, a guard boat « Sikine » belonging to the Maritime Safety Board was despatched there on the same day, in order to mark clear the exact position of the submarine eruption. According to the report from the guard boat, its position was surveyed with the result of 31° 56′.7 N and 140° 0′.5 E, and at the time of the survey, the submarine volcano showed its top part above the sea level in a form of a small islet or reef, of which the size was estimated at 100 m long in its E-W diameter, 150 m long in its N-S diameter and 30 m high.

After this brief information was brought to us, volcanologists, geologists and oceanographers went there to observe the submarine eruptions by aeroplanes and on board ships. Of these expeditions, the observation-boat, « Kaiyo-maru

No. 5 » of the Hydrographic Office, which started on September 23, from Tokyo, was lost with all the men aboard this ship, her crew of 22 men and 7 scientists including Dr. R. Tayama and Dr. K. Kawada.

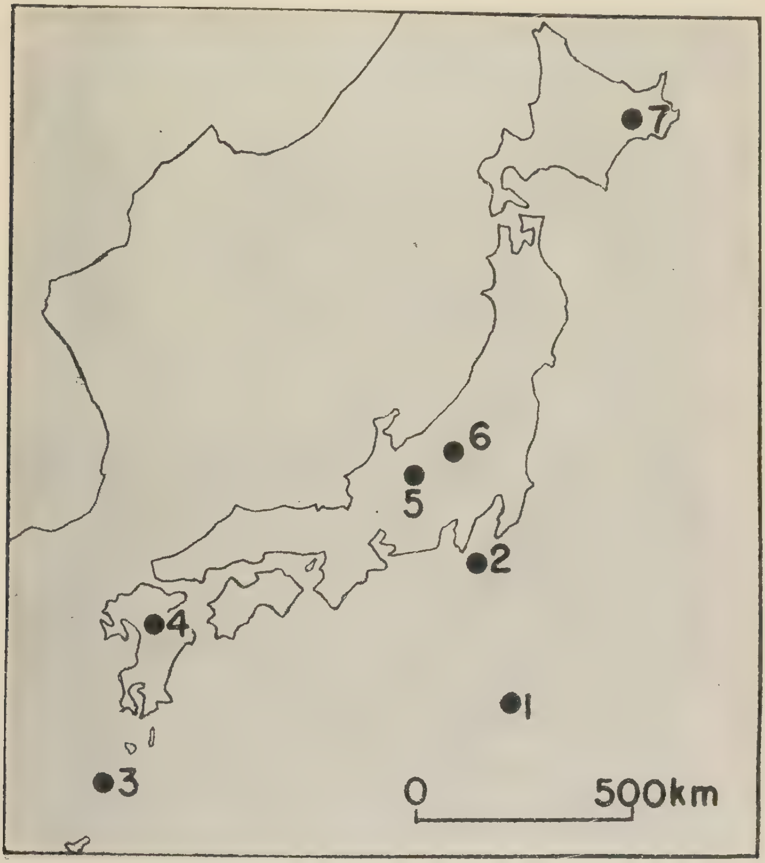

Fig. 1. - Geographical positions of the volcanoes active in the period from 1951 to 1954.
1, Myozin-syo, 2, Oo-sima, 3, Suwanose-sima, 4, Aso, 5, Yakedake, 6, Asama, 7, Meakan.

2) Historical eruptions of this submarine volcano

The Huzi (Fuji) volcanic belt, reaching from volcano Huzi to the Mariana Islands, consists of many a number of active and extinct volcano islands among which this submarine volcano is included. However, these volcanoes are not similar to

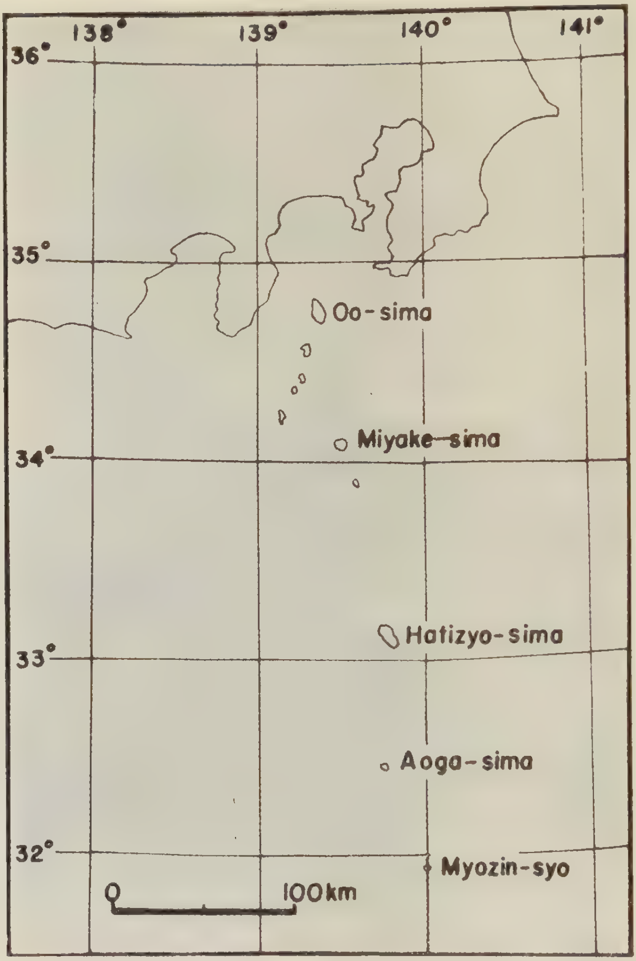

Fig. 2. - Geographical position of Myozin-syo (submarine volcano).

one another with respect to their chemical and petrographical characteristics and accordingly the natures of volcanic phenomena. For this reason, some volcanologists have classified them petrographically into three or more groups.

Up to the present eruption of the Myozin-syo, we had no precise information concerning the natures of this volcano.

Only brief records show that this submarine volcano erupted several times in this century. In Table 2, the dates and rough positions of eruption are summarized on the basis of various records.

The localities in this Table 2, do not harmonize perfectly with one another nor with the result of the present survey. However, it is evident that this discrepancy is mainly caused by the inaccuracy in the former determinations of position, for most of the former observations were made accidentally by boats passing at a long distance.

Table 2. - Record of the submarine eruptions (in the neighbourhood of 31° 57′ N, 140° 00′ E.). (After Hydrographic Office).

Date	Location	Remarks
1896	About 14 km north of the Bayonnaise rocks.	Observed newly formed reef.
Apr. 1906	In the vicinity of the Bayonnaise rocks.	Observed eruption.
Feb. 1915	About 12 km east of the Bayonnaise.	Observed bank 10 km in the depth.
May 1934	About 9 km east of the Bayonnaise.	Observed yellow colour water with sulphur smell.
Feb. 1946	31° 57′ N, 140° 01′ E.	Newly formed islet, 200 m long, 150 m wide.
Apr. 1946	31° 57′ N, 140° 01′ E.	Newly formed islet including two spines, each 100 m high.
Oct. 1946	» , » .	One spine only.
Dec. 1946	» , » .	No spine, wave break on bank.
Sept. 16, 1952	31° 56′ N, 140° 00′.5 E.	Recent eruption.

3) Brief description of the 1952 - 1953 eruptions

According to observations by K. WADATI, T. MINAKAMI and A. SUWA by aeroplane, on 17 and 18 September 1952, Myozin-syo was erupting every few seconds at brief intervals, throwing incandescent bombs and ash with vapour, though ebbs and flows in eruption appeared every few minutes.

Although we have no information as to the exact date when the present activity started, it seems that the incessant eruptions as mentioned above lasted for several days at its earlier stage, and resulted in filling the shallow sea around the crater of this submarine volcano. According to their estimation, the size of the newly formed islet at the time was not much different from that measured by « Sikine ».

However, it seems that the nature of eruption changed remarkably soon after their observation, or to be more precise, paroxysmal eruption took place not only at longer intervals but also with stronger intensity which resulted in conspicuous decrease of supply of new ejecta as compared with the earlier stage. For this reason, the new islet was exceedingly subject to erosions of sea waves and partly to destructive forces of explosive eruptions. Through the process mentioned above, the Myozin-syo vanished at last from sight towards 21 or 22 of the same month, only about one week after its birth.

However, paroxysmal eruption in the submarine broke out one or three times per day, during the period from the disappearance to the end of September, and thereafter at longer intervals.

The activity of the Myozin-syo volcano was in the state just mentioned, when a number of scientists including H. NIINO, H. TSUYA, R. MORIMOTO, S. MURAUCHI, R. TAYAMA and K. KAWADA etc. went there to investigate this volcano aboard two ships, one being « Sinyo-maru », a training boat of the Tokyo Fisheries University, and the other, « Kaiyo-maru No. 5 » of the Hydrographic Office.

The investigators including the former four scientists on board « Sinyo-maru » came fortunately upon an extraordinary submarine eruption at a distance convenient for observations on 22 and 23 September. It was indeed unfortunate that the latter boat should have encountered a furious explosion at the nearest distance on the following day (24 Sept.), which resulted in the death of all men aboard including R. TAYAMA and K. KAWADA.

The features of the submarine eruption were brought to light in detail by the observations made by the former investigators. Especially it is lucky that precise developments of the remarkable eruption on 23 September were caught by a series of documentary pictures taken by Y. SUGANO, the cameraman of the Asahi Press, as may be seen in Figs. 15-17.

It may be said on the basis of these pictures, that a water dome formed simultaneously with the commencement of eruption on the sea surface just above the submarine crater, and few seconds later numerous bombs, gravels and ash were thrown up into the air through the water dome, for a space of few minutes. The disturbances of the sea water, originated from the water dome and the fall of abundant ejecta, propagated on the sea surface in form of the Tsunami-waves.

The activity ceased towards August 1953, one year after its commencement. Reviewing this activity, we experienced several times the cycle including the two stages, the first of which is the growing stage of the Myozin-syo Volcano with incessant eruptions and the other its decaying stage in the dormant period.

It must be added that those volcanic phenomena including the birth and disappearance of the newly formed islet are markedly analogous in various respects, especially at the earlier stage of its birth, to the submarine eruptions of Anak-Krakatau which were studied closely by Dutch volcanologists.

In Table 3, the dates and short accounts of the present eruptions are summarized on the basis of the records collected by the Hydrographic Office and the Hatizyo-sima Weather Station.

Table 3. - Record of the eruptions of Myozin-syo (1952-1953).
(After Hydrographic Office)

Date	Data
1952	
17 Sept.	7h 15m. Eruption. New islet on 17′ NNE Bayonnaise. (32° 10′ N., 140° 05′ E.).
18 Sept.	9h 00m. Small eruption. Newly formed islet is 150m long (NS), 100m wide (EW), 30m high. Yellow coloured water streams for SSW. (31° 56′.7 N., 140° 00′.5 E.).
22 Sept.	15h 00m (3h 00m p.m.), 23h 45m. Eruptions observed from Hatizyo (Hachijyo) Island.
23 Sept.	8h 34m, 13h 12 m, 13h 40m, 19h 00m. Eruptions. The islet disappeared, wave breaks on shoals. Yellow coloured water streams for SSW. (31° 56′.8 N, 139° 59′.5 E.).
24 Sept.	5h 40m. Large submarine eruption at 10′ E of Bayonnaise. No islet was seen.
24 Sept.	Large eruptive sound at nearly morning. Two columns of eruption cloud at noon, the eastern one constant and the western one occasional.
24 Sept.	13h 50m. Tsunami 2m high at Hatizyo.
25 Sept.	5h 00m. Falling ash.
25 Sept.	13h 30m (unreliable), 18h 30m. Large submarine eruption.
26 Sept.	12h 35m. Very large submarine eruption, 1′ wide. Sand (ash) fell 2′ (4′) wide.
3 Oct.	5h 45m, 8h 00m. Submarine eruptions.
11 Oct.	3 peaks like spines on the sea, the middle one highest (80m). Width 150m, length 200m.
21 Oct.	21h 50m. Small eruption, the islet is 30m high.
7 Nov.	The islet 30m high. Abundant quantity of eruption cloud.

Date		Data
12	Nov.	2 islets in a row, N to S.
17 18	Nov.	Eruptions, heigth of cloud 500-600m.
24	Nov.	Black cloud erupted. The islet is 300m long and 100m high. (31° 54′ N., 140° 2′ E.).
1953		
19	Jan.	North peak 94m high, south peak 56m high, water vapour rise from shore.
1	Feb.	North peak 93m high, south peak 54m high, 220m long. 151m wide.
6	Feb.	16h 00m. Eruptive cloud. Observed a new islet which is as large as Smith Islet.
2	March	Cloud increased.
6	March	120m high. Eruptive cloud.
9	March	Since 9th March, successive eruptions.
11 25	March	Tsunami at times.
17 18	March	Large eruptions.
30	March	Very great eruptions (3 times large, as large as the one which wrecked Kaiyo-maru No. 5).
1	April	5h 40m-17h 00m. Eruptive smoke.
1	April	15h 00m. Eruptive cloud on 172° 59′, height 20′, width 1′-5′. Vanished next day.
1	April	3 columns of eruptive cloud (the eastern one large).
5	April	9h 41m. Eruptive cloud observed. New volcanic islet about 60m high. (31° 53′ N, 140° 10′ E.).
Mar.-Apr.		Red-black coloured water with drifting pumice came from Myozin-syo.

Date	Data
14 April	3 peak almost equal in height (46m) form a line from N to S 200m long. (31° 56′.7 N,, 140° 08′.5 E.). The azimuth of Myosin-syo (middle) from the north rock of Bayonnaise is 71° 0′.
14 April	Yellow coloured water drifts to SE from Myozin-syo.
3 May	Peaks (50m high in average, Max 70m) form a line from NNE to SSW, 250m long.
9 21 May	2 peaks (43m high) but western one obscured by vapour. 151m wide. (31° 56′ 40″ N., 140° 0′ 26″ EN Peak).
26 May	Weak explosive sounds.
17 July	No eruptive cloud.
18 July	5 rocks.
23 July	Pinnacle rock appeared at center. 2 small rocks on S-side and vapour issued from them.
12 Aug.	Islet seems smaller (about half that size in May), summit obscured by smoke.
17 Aug.	Vapour began to increase.
24 Aug.	6h 00m-7h 00m. Large eruptive cloud, islet invisible. 10h 00m. » 13h 30m. Large eruption. 14h 00m. Cloud became white.
26 Aug.	22h 00m. Red lava flows into the sea. Falling ash.
27 28 Aug.	Large eruptive cloud.

Date	Data
1 Sept.	7h 30m. Eruption. 13h 00m-14m. Erupted sand, width 200m, height 500m. No flame at night.
3 Sept.	Eruptive cloud, but no islet seen. 2 breakers in the vicinity of Myozin-syo. Yellow coloured water drifts to WSW.
16 Sept.	No islet seen. (Visibility 40′).
17 Sept.	Eruptive cloud. No islet. The water turned yellow in the vicinity of Myozin-syo 5′ wide.
27 Sept.	12h 18m. The sea water muddied white on 11′ N. of Bayonnaise.

4) Brief description of investigations on Myozin-syo

R. Mita of the Hydrographic Office made in 1949 the map of the Submarine topography in the vicinity of the Myozin-syo Volcano, on the basis of the result of sounding. According to his map, a submarine volcano exists in the shape of a cone of which the top reaches just below the sea surface. The diameter at the base of this cone and its height measured from the base are nearly 8 km and 1 km respectively. At 12 km, W of the Myozin-syo Volcano, there is another formation of volcano hidden under water and its top part above sea surface is called by the name of the Bayonnaise rocks. Judging from the features of the submarine topography of this area, R. Mita was of opinion that the latter formation including the Bayonnaise rocks constitutes a part of the somma for the former submarine volcano, Myozin-syo.

To make the point clearer he went there aboard the Kaiyo-maru only to become one of the victims of the disaster on 24 September.

On 1 February, 1953, soon after the present activity of the submarine volcano, the training boat, « Umitaka-maru », of the Tokyo Fisheries University, resurveyed the submarine topography, to detect changes in the topography caused by the present eruption.

On account of the difficulty of access and dangerous character of eruption we could not collect sufficiently lava specimens ejected from Myozin-syo in its various stages. However,

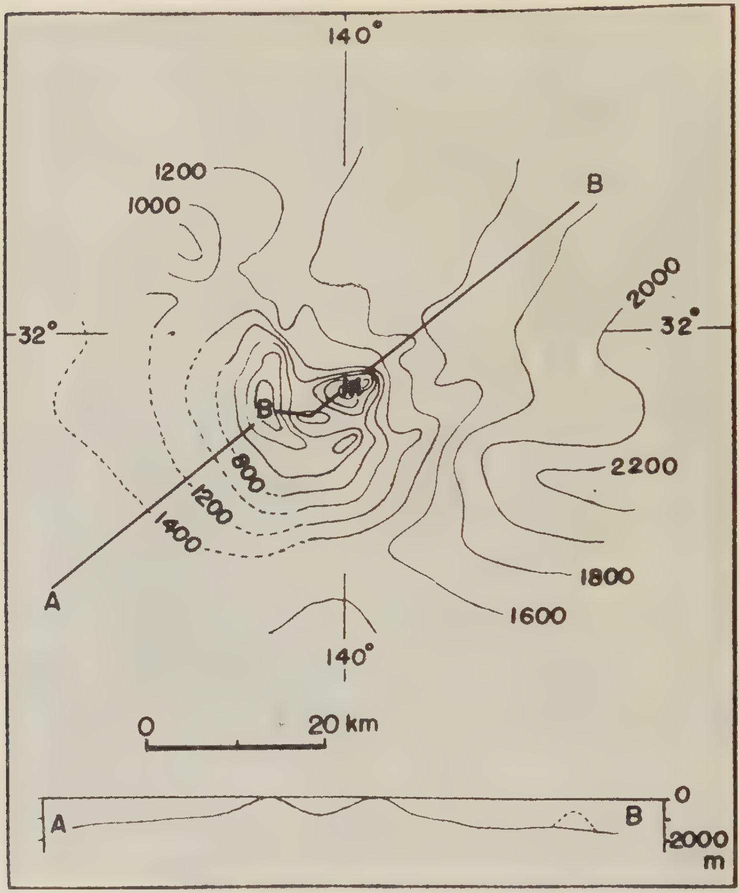

Fig. 3. - Submarine topography near Myozin-syo and the Bayonnaise rocks.
(After R. Mita, Hydrog. Office)

fortunately a floating block of pumice in hot state was picked up just after its ejection by the investigation ship « Sinyo-maru » on September 22, 1952. The block picked up was 30 cm × 40 cm × 100 cm in its size, of white colour and very much porous.

According to microscopic investigation, H. TSUYA and R. MORIMOTO classified the pumice as two-pyroxene quartz dacite, in which porphyritic crystals of high quartz, hypersthene, augite and iron are scattered.

G. OSSAKA analyzed chemically the same specimens of pumice with the results given in the following Table 4.

Table 4. - Chemical Analyses of the Pumice from Myozin-syo and Bayonnaise Rocks.

I. Main white portion of the pumice ejected at 13 h 40 m, Sept. 23, 1952, from Myozin-syo.
II. The pumice found in a wooden barrel of No. 5 Kaiyo-maru.
III. Greyish patches included in the above mentioned white pumice ejected 13h 40m Sept. 23.
IV. Lava specimen of the Bayonnaise Rocks collected by W. WOOSTER and R. FISHER.

	I	II	III	IV
SiO_2	68.23 %	65.39 %	63.30 %	51.95 %
Al_2O_3 . . .	14.31	14.99	16.10	18.85
Fe_2O_3 . . .	1.75	1.98	3.13	4.21
FeO	2.92	3.15	3.80	6.72
MgO	1.51	1.47	2.77	3.96
CaO	4.51	5.27	6.12	10.85
Na_2O	3.90	3.69	2.67	1.89
K_2O	0.75	0.63	0.51	0,24
H_2O (+) . .	0.37	0.81	0.52	0.21
H_2O (—) . .	0.18	0.67	——	0.18
TiO_2	0.59	0.70	0.79	0.86
P_2O_5	0.10	0.14	0.13	0.07
MnO	0.08	0.10	0.18	0.18
NaCl	0.53	0.63	——	0.05
S	0.12	n.d.	n.d.	n.d.
Total	99.85 %	99.62 %	100.02 %	100.22 %

(Analyzed by G. OSSAKA)

The specimens of the Bayonnaise Rocks were collected at the first time in 1953 by W. Wooster and R. L. Fisher of the Scrips Institution of Oceanography. The specimen was chemically and microscopically analyzed by R. Morimoto and G. Ossaka. As the result, they classified it petrographically into hypersthene-augite-basalt with the following chemical property. It will be a common feature that the somma rocks are more basic as compared with those of the central cones. Therefore, the relation of chemical property between the Bayonnaise and the Myozin-syo rocks does not contradict with Mita's assumption that the former may be the somma formation of the Myozin-syo.

Judging from the results of the chemical analysis of the lava specimens which contain nearly 65 % of silica, T. Minakami remarked that its viscosity at the moment of eruption should have been exceedingly great as compared with that of the basaltic lava. Moreover, the lava which existed in the vent of Myozin-syo might have been influenced gradually by sea water in the course of the present eruption, which resulted in the cooling down and the partial solidification of the lava at the latter stage. Therefore, it may be inferred that the nature of eruption assumed more and more an explosive character and tours of lava like spines appeared on the sea surface towards the end of the present activity.

On the other hand, S. Murauchi estimated the energy of the eruption on 23 September, 1952, at 10^{19} erg from the magnitude of the Tsunami caused by the eruption, which is comparable in the energy to that of a marked eruption of Asama.

5) The disaster of the Kaiyo-maru No. 5

Kaiyo-maru No. 5, a ship for marine observation, belonging to the Hydrographic Office of the Maritime Safety Board in Japan, sailed from Tokyo at 10h 55m a.m. on 23 September, 1952, in order to determine the accurate locality of Myozin-syo and to resurvey the submarine topography in its vicinity. The ships schedule was to come back to the mainland by the 25th of the same month. However, she was lost after the last telegram was despatched on the sea off Miyakesima at 8h p.m. on the day of her start.

From Sept. 25, the Maritime Safety Board searched for the ship with all its might by means of aeroplanes and patrol boats, but in vain. On Sept. 27, a buoy and wrecked materials from the Kaiyo-maru were discovered on the southern sea of Myozin-syo. As the result, it was reasonable to infer that the ship had been already wrecked by an unexpected catastrophe.

As soon as the catastrophic accident was confirmed, a committee for investigating the catastrophe was organized by members of various institutes including geologists, geophysicists and engineers. After precise investigations based on the evidences collected and various kinds of laboratory experiments, the committee drew the following conclusion: the ship seems to have capsized suddenly owing to furious close-range submarine eruption of the submarine crater towards 12h 30m on Sept. 24.

Although there is no eye-witness for the occurence of the eruption at the date and time mentioned above, this assumption was shown be reasonable by the following evidences.

i) Record of the tsunami-wave at Hatizyo-sima.

The tide gauge that was operated by the Hatizyo-sima Weather Station, 120 km to the north Myozin-syo, recorded frequently the tsunami-waves originated from the present submarine eruptions. In examining those records, M. Nakano and his associates found a tsunami-wave which commenced at 12h 53m ± 6m on Sept. 24. According to their calculations of propagation of the tsunami-wave, the travel time is about 28m from Myozin-syo to the tide gauge. Therefore, it is very natural to conclude that the tsunami-wave or the submarine eruption took place at 12h 25m ± 6m.

ii) Record of the SOFAR hydrophone at the western coast of U.S.A.

R. S. Dietz of U.S. Navy Electronics Laboratory carried out continous observation of sound propagating in the sea at two places at the western coast of the United States and one at Hawaii. His hydrophones recorded a great number of the sea-sounds which were originated from respective eruptions

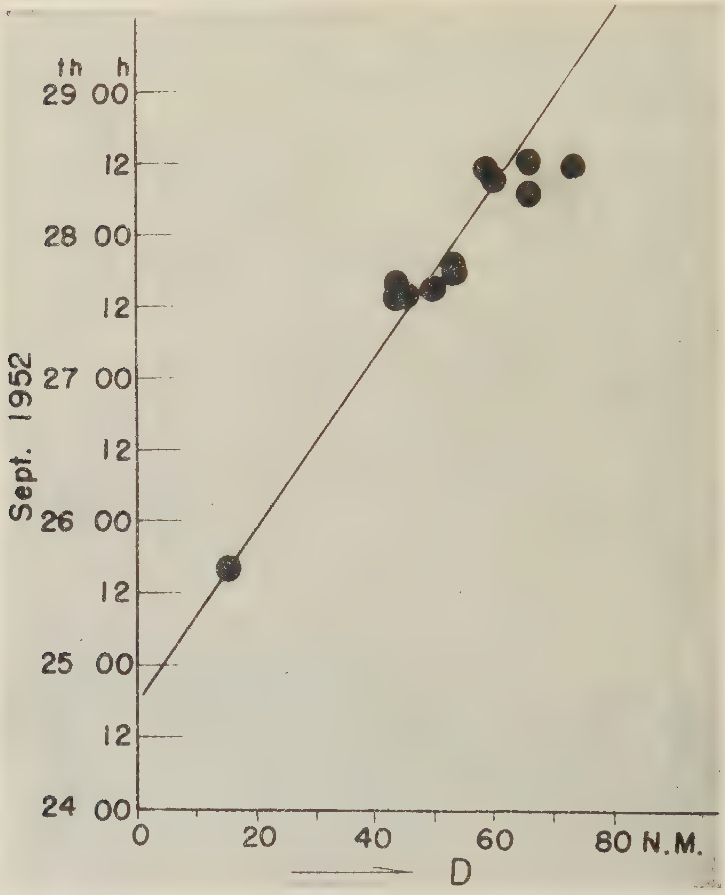

Fig. 4. - The positions (or distance from Myozin-syo) of the floating materials from Kaiyo-maru No. 5 and the times which they were discovered respectively.
(After Hydrographic Office)

of Myozin-syo and propagated through the Pacific Ocean. Taking the travel time of the sea sound through the SOFAR layer into consideration, he verified the submarine eruption of Myozin-syo as approximately 12h 30m Sept. 24.

iii) The distribution of floating materials from the wrecked ship.

The wreckages of the Kaiyo-maru No. 5, which drifted on the ocean current, were found on the southern sea from 25th to 28th of September. The relation between the position of these wreckages and their travel times supports the assumption that they flowed from Myozin-syo or somewhere quite near it at the same time, namely towards 12h 30m, Sept. 24.

iiii) Fragmental ejecta found in the wreckages.

We found numerous pieces of fragmental lava and pumice stuck into these wreckages. These fragmental pumices were studied petrographically and chemically in comparison with the pumice erupted in the 23th eruption of Myozin-syo, by R. Morimoto and G. Ossaka. As the result, they remarked that there would be no special objection to conclude that these two specimens originated likewise from Myozin-syo.

3. - Volcano Aso 20) - 21)

During the period from 1951 to 1954, eruptions took place only inside the first crater, the northmost one of the five summit craters. The eruption on 27th of April, 1953, was most intense in this period, throwing numerous lava blocks and volcanic bombs not only around the margin of the crater, but also to the base of the central cone, 0.6 km distant from the crater.

At the time of the eruption, there were many people for sight-seeing at the brim and inside the crater, of whom five men were killed and scores of men wounded hit by large and small ejecta.

The earthquake caused by this eruption was felt as far as 1 km distant from the crater. According to the seismometrical observations at the Aso Weather Station, volcanic tremors of continuous train became distinctly larger in their amplitude from April 6, 1953, three weeks before the commencement of the 1953 eruption. However, they became small for several days directly before the eruption. It must be added that a similar relation between volcanic tremors and eruption was observed in the 1950 activity of this volcano as reported in the previous Bulletin.

To determine the topographic deformations of this volcano, K. Sassa conducted precise levellings along the route from the base of the mountain to the summit, the result being that the summit subsided 9 cm in the period from 1942 to 1951 and upheaved nearly 2 cm in the succeeding two years, both compared with the base of the mountain.

Table 5. - List of the Aso eruptions which occurred in 1951-1954.
(After Aso Weather Station)

Date	Brief description
1952	
Aug. 3	Vapour of black colour with fine ash.
1953	
Apr. 8	Volcanic ash and sand ejected 150m high.
» 27	At 11h 31m, explosive eruption with abundant ejecta and vapour of black colour.
» 28	Fragmental lava and fine ash ejected.
» 29	Activity similar to the previous day.
May 4	Ash scattered to the northern foot.
» 24	Fragmental lava with vapour of greyish colour ejected.
June-Aug.	Very small eruption with slight ash, sometimes with rumblings.
Sept.	Intermittent rumblings and fine ash.

4. - Volcano Asama 22) - 25)

1) The 1953 - 1954 activity of Mt. Asama

After the strong explosion of September 23 in 1950, Volcano Asama was in a very quiescent state up to the beginning of August of 1953. However within only 20 hours between the 2nd and the 3rd of August, 1953, more than 200 microearthquakes took place in the form of a swarm in the vicinity of the summit crater. Simultaneously with this swarm, the volume and nature of the vapour and volcanic gas from the crater became irregular and at times was abnormally abundant and especially rich in SO_2, but at other times the vapour and volcanic gas were extremely slight and contained little SO_2. On the basis of observations in the past 20 years, this variation in the amount and composition of the volcanic gases commonly precedes a stage of activity in Asama.

On December 20, 1953, and after, rumblings were heard at the Asama Volcano Observatory which is located 4.2 km east of the summit crater.

At 13h 43m on December 27, a small eruption broke out and a small amount of ash was emitted. After that, Mt. Asama erupted very frequently up until March 1954. The magnitude of these eruptions was extremely small as compared with the usual explosive eruption of this volcano.

In the past fifty years the pattern of activity in Mt. Asama has been far actively to reoccur on the average of 2 or 3 years. The activities consist of scores of explosive eruptions of various magnitudes. The energy of these respective eruptions was estimated at from 10^{20} erg to 10^{12} erg, and at 10^{18} erg in its mean value. Moreover, these eruptions usually took place with a mean interval of several days, even at a markedly active period.

However, the present eruptions were very different in various respects. For instance, each of the present eruptions took place at short intervals, that is from several hours to twenty hours, and had an extremely small amount of energy ranging from 10^{16} erg to 10^{12} erg. Therefore, although the total fre-

Table 6. - Daily frequency of the 1953-1954 eruptions of Mt. Asama.
(After Asama Volcano Observatory (E.R.I.))

	1953 Dec.	1954 Jan.	Feb.	March	April	May
1	0	0	1	4	1	0
2	0	0	2	0	0	1
3	0	3	8	2	1	0
4	0	0	6	0	0	0
5	0	1	5	1	0	2
6	0	2	2	1	0	0
7	0	2	4	3	1	0
8	0	8	1	1	0	2
9	0	0	0	2	1	0
10	0	1	3	0	0	1
11	0	5	7	3	1	0
12	0	10	0	0	0	3
13	0	3	6	1	0	3
14	0	1	4	3	0	1
15	0	3	7	0	1	2
16	0	8	2	0	0	0
17	0	7	3	4	2	3
18	0	1	1	1	0	2
19	0	3	3	1	3	2
20	0	4	1	2	4	1
21	0	7	0	0	0	0
22	0	3	4	2	0	0
23	0	4	3	2	1	1
24	0	1	2	4	2	0
25	0	1	0	2	3	2
26	0	1	1	0	0	3
27	2	0	0	2	1	0
28	3	2	0	0	2	1
29	4	2		0	1	1
30	2	1		0	2	3
31	1	1		0		1

quency of eruptions amounted to 200, the total energy of these eruptions was estimated at only 10^{18-19} erg, which is comparable to that of a marked eruption in this volcano such as experienced in the 1950 and 1947 activities. According to the records of Asama eruptions in the past thirty years, this type of eruption now occurring also took place in the period from December 1940 to March 1941.

2) Instrumental observations of Mt. Asama

Various geophysical observations have been continuously carried out since 1933 at the Asama Volcano Observatory (Earthq. Res. Inst., Tokyo University), which is equipped with such instruments as highly sensitive seismographs, clinographs, magnetographs, and extensometers. Besides the permanent observations at our Observatory, which is located 4.2 km to the east of the summit crater, seismometrical and other observations were made at five other stations, including temporary ones, distributed around the crater and at the foot of the volcano.

T. Minakami, S. Sakuma and their associates investigated micro-earthquakes originating from the volcano at the five stations in 1951 and 1952, and at six stations in 1953, to determine the localities of their hypocenters. For the purpose, they observed mechano-optically by means of sensitive horizontal seismographs, of which the instrumental constants are each 1.0 second in period and 4000 in magnification. In order to determine precisely the initial time of the micro-earthquakes at each station, the time signals of every second which are broadcast from the Tokyo Astronomical Observatory were recorded directly in the seismograms.

On the basis of the seismograms obtained at five or six stations, the positions of the hypocenters of the micro-earthquakes were determined by means of the least square method by using their initial time and their duration of preliminary tremors at each station. Since the initial motion of these earthquakes were of exceedingly small amplitude, which is a common character of the extremely shallow earthquakes, the exact positions of the hypocenters were determined for the largest 24 earthquakes in August, 1953.

The geographical distributions of the hypocenters are illustrated in Fig. 5. At a glance of the figure, it is clear that the hypocenters are concentrated in the vicinity of the summit

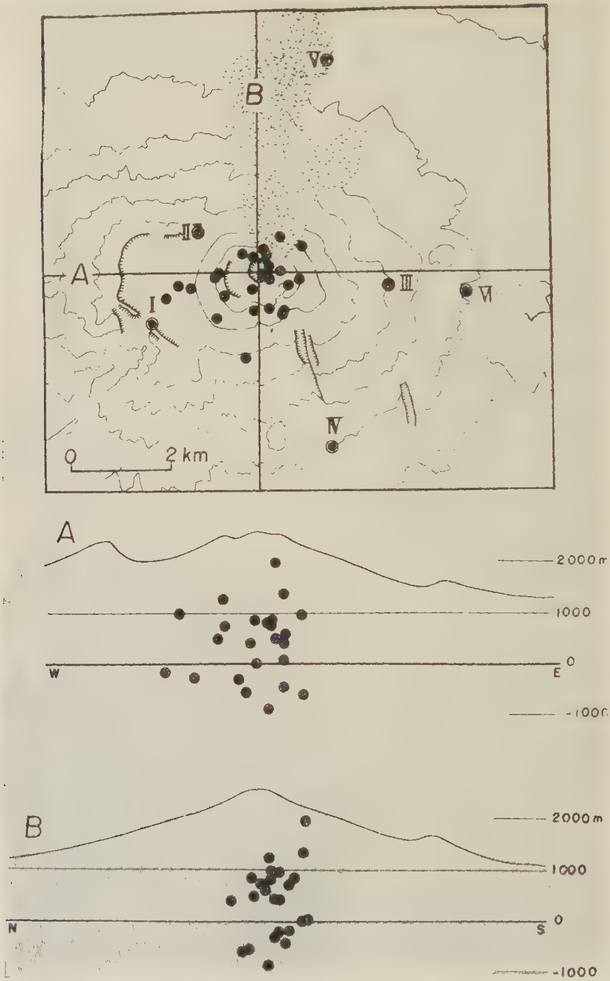

Fig. 5. - Distribution of micro-earthquakes originating from Mt. Asama in Aug. 1953.
(After T. Minakami and his associates, E.R.I.)

crater and below it. Moreover, the depth of these hypocenters

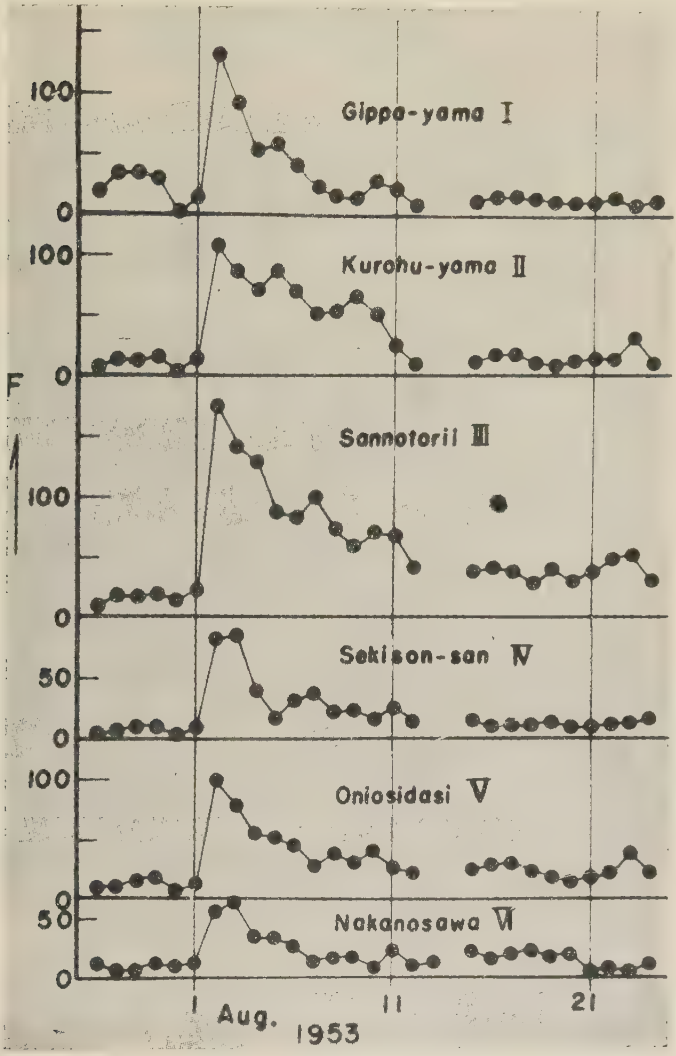

Fig. 6. - Daily frequency of micro-earthquakes at six stations on Mt. Asama.
(After T. Minakami and his associates, E.R.I.)

are markedly shallow, as compared with those of earthquakes of tectonic origin, notwithstanding the fact that the earthquakes shown on the maps in Fig. 5, are believed to be deeper than those of other earthquakes in the same periods.

Moreover, it is remarked that the earthquakes in 1953 including the earthquake swarm took place in the larger domain around the crater and vent than those of 1952, and the 1953 domain is elongated to the east-west direction, being limited in the north-south. This may suggest the structure of the volcano or existence of a fissure running from west to east through which fresh lava, volcanic gases are supplied up to the crater, though the problem demands consideration of other evidences.

In order to investigate the mode of the earthquake swarm in August 1953, the daily frequency at the six stations is represented in Fig. 6. These six curves are remarkably similar in their general trends, though their absolute values are different greatly from one another. On the other hand, the amplitudes of these earthquakes which were recorded at the six stations are almost proportional to the total number of earthquakes at each station. Therefore, it is reasonable to assume that most of these shallow earthquakes took place in a limited domain which is located near the Station No. 3 and the summit.

In order to make the problem more precise, the position of the center of the epicentral area for these numerous earthquakes is given by the following assumptions. The total frequencies of earthquakes observed at each station decrease proportionally with the distance from the center of the epicentral domain.

Therefore,

$$F = F_0 (1 - kr)$$

In the above expression, F, F_0, r and k are as follows,

F, frequency at each station,

F_0, frequency at the center of the hypocentral domain,

r, distance from the hypocentral domain to each station,

k, constant or decrease factor of frequency.

On the basis of the frequencies observed at the six stations and by means of the above expression, the position of the 1953 hypocentral domain and the other elements (F_0, k) were determined and the 1951 and 1952 domains were also given by the same procedure as mentioned above. These positions are represented on the map of Fig. 7. As will be seen on the map of Fig. 7, these positions of the center of earthquakes moved from the crater toward east in recent three years. Moreover, it is interesting to note that the 1953 center does not coincide with the locality of the 24 largest earthquakes shown in Fig. 5. Therefore, this result shows that comparatively larger and deeper earthquakes took place under the summit crater and extremely small and shallow ones

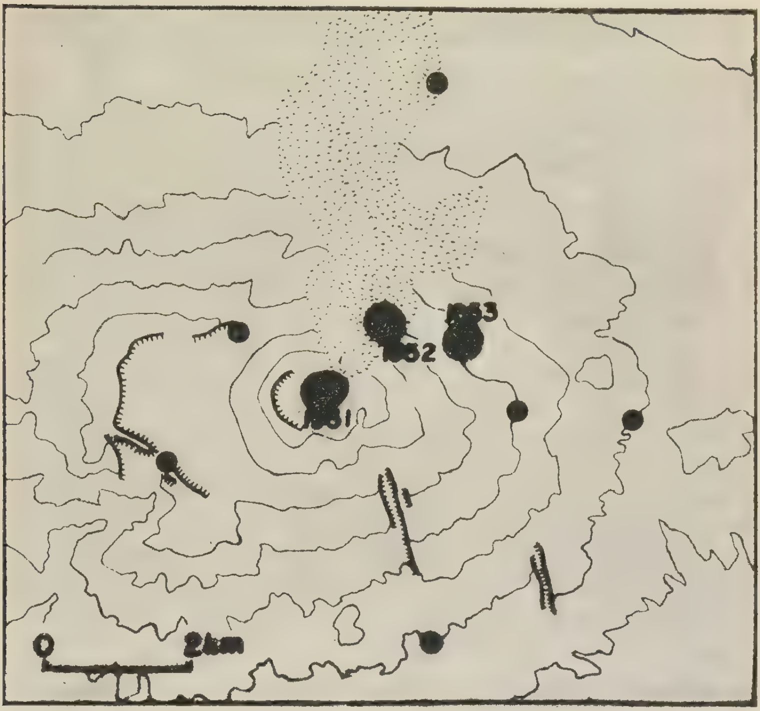

Fig. 7. - Positions of the epicentral areas of extremely shallow earthquakes originating from Mt. Asama in 1951-1953.
(After T. Minakami and his associates, E.R.I.)

concentrated at the north-east flank 1.5 km distant from the crater.

For about one month preceding the eruption from December 27, 1953 to April, 1954, the frequency of earthquakes increased to some extent as compared with that of the quiescent period. And in the course of the present activity, we observed not only markedly frequent earthquakes with larger amplitudes, but also volcanic tremors of continuous train, of

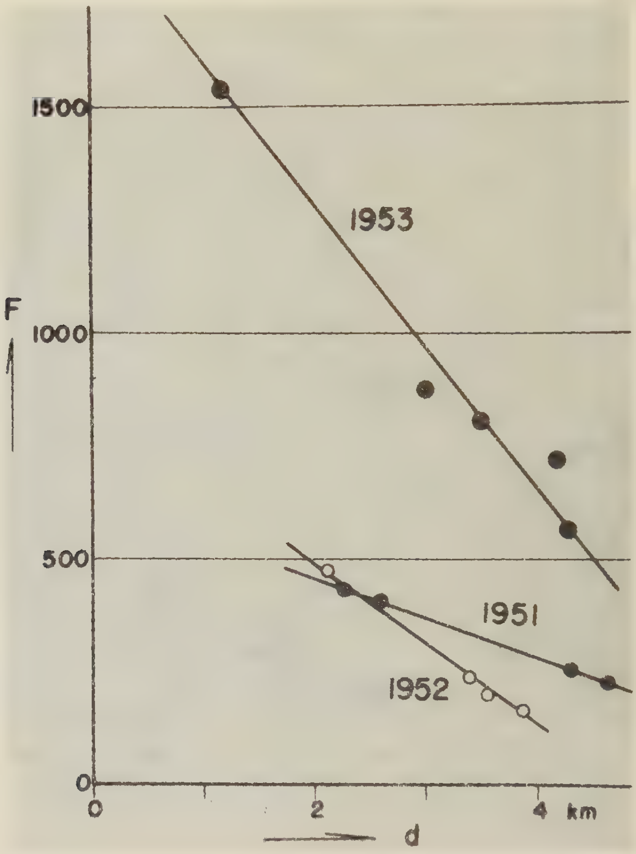

Fig. 8. - Monthly frequency (F) of micro-earthquakes in August (1951-1953) which were observed at 4 or 5 stations and distance (D) from the center of epicentral area.

(After T. MINAKAMI and his associates, E.R.I.)

which the vibration periods ranged from 0.3 sec. to 0.7 sec. and had 0.4 sec. in average.

4) Precise levelling and gravimetric survey

Topographical deformations on active volcanoes and in their adjacent areas are the most attractive phenomena for us in connection with their eruptions and in the close relations to formation of the caldera. To throw light on this problem, levelling routes running through the summit, flanks and foot of this volcano were newly established in 1934 and 1950-1954. The net work of these levelling routes is directly connected to the bench marks on the Tertiary formation located

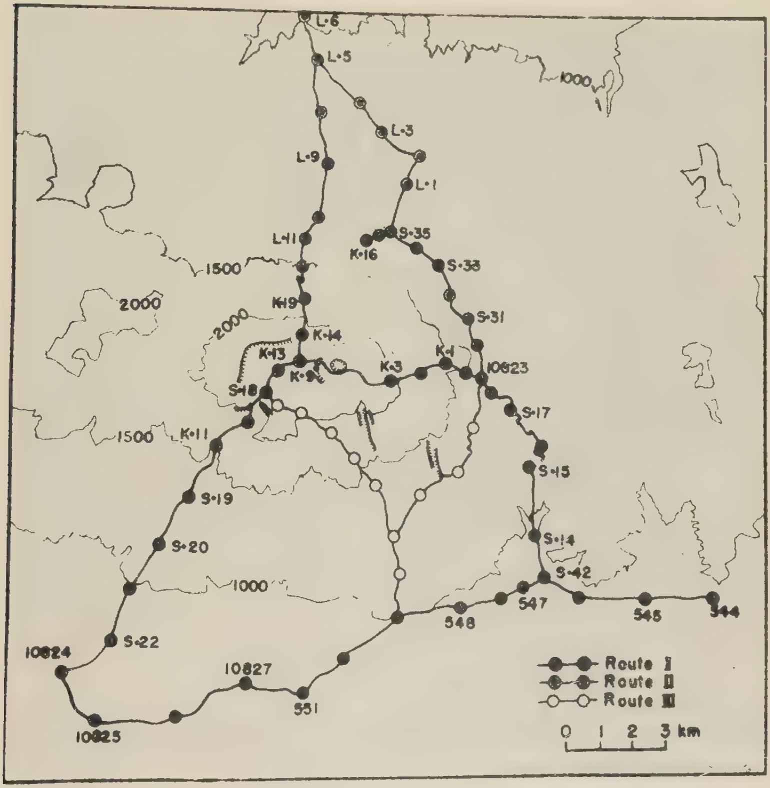

Fig. 9. - Net work of levelling routes on and around Mt. Asama.

12 km to the south-east of the Asama summit, which corresponds to the base formation of Asama.

Topographical deformations along the 1934 route which runs through the summit were made clear by two series of levelling which were conducted in 1934 and in 1951. The result in Fig. 10 shows clearly that the summit area upheaved remarkably in a dome-shape in the past seventeen years, and the surrounding area from the middle flank to the foot of the mountain subsided in a form of a ring. However, it may be said that such a mode of topographical deformations is a common character to those accompanying the summit eruption, on the basis of a number of examples at other volcanoes, such as in the 1913 eruption of Sakura-sima, and in the 1910 and 1943-1944 eruptions of Usu. However, it is important and interesting to make clear the problem whether the subsidence of a ring form at the foot of active volcanoes after their

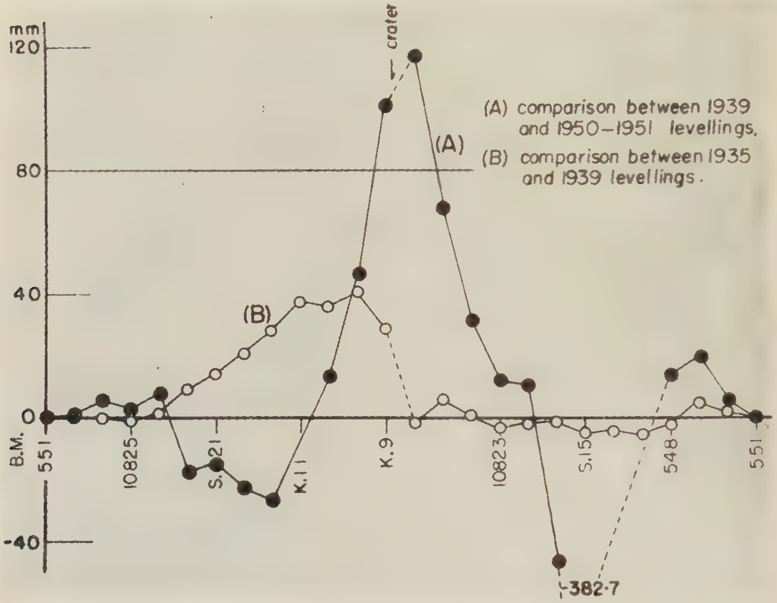

Fig. 10. - Result of levelling covering Mt. Asama.
(After T. Minakami and A. Okada, E.R.I.)

eruptions is the phenomenon of undeveloped stage of the caldera formation or not. For the purpose, we are now examining the problem by covering various active volcanoes in Japan with the net work of levelling route.

It must be added here that the rising area at the summit part of Asama agrees perfectly with the epicentral area indicated in Fig. 5. This agreement will be rather natural, seeing that these two phenomena were both caused by dynamical pressure originating from the magma which exists in the vent and in the lava reservoir.

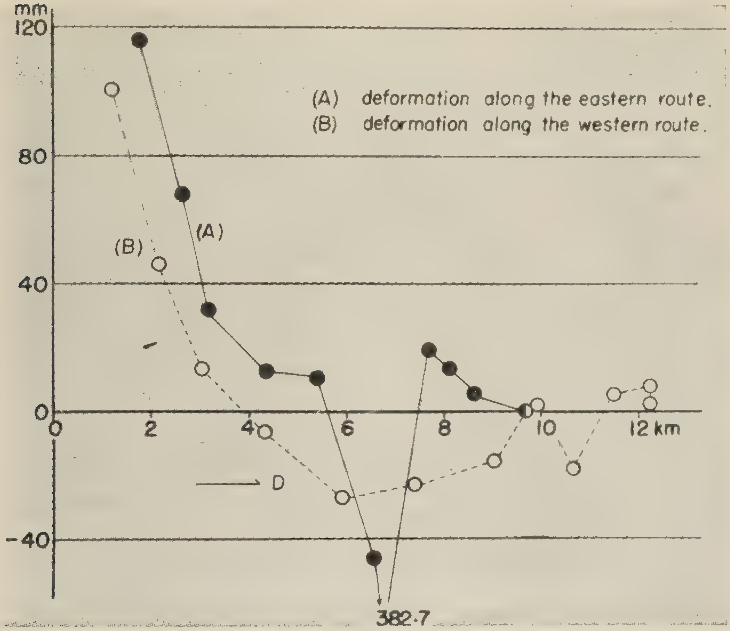

Fig. 11. - Upheaval of a dome shape around the summit crater and subsidence around the rising area which appeared for 13 years from 1939 to 1951.
D: distance from the summit crater.
(After T. Minakami and A. Okada, E.R.I.)

For investigating the structure of the volcano and variation of the mass distribution inside the volcano accompanying eruption, we planned gravity survey in co-operation with C. Tsuboi. The measurements of gravity were made in 1952 and

1953 with a Worden gravimeter on the series of the bench marks indicated in Fig. 9, on which the height above sea-level was precisely given. As the result of the survey, the distribution of Bouguer anomaly was brought to light in the area covering Mt. Asama.

As the result of the gravimetric survey, it was found that

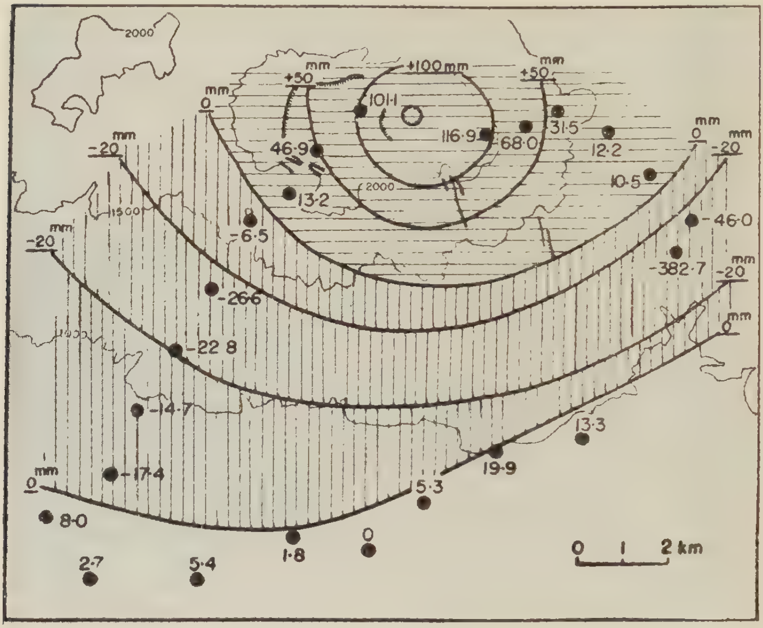

Fig. 12. - Topographical deformation of Mt. Asama in the period from 1939 to 1951.
(After T. Minakami and A. Okada, E.R.I.)

the gravity anomaly is remarkably positive at the western part of the crater, and negative at its eastern part including the central cone. It is in fact remarkable that the positive and negative anomalies amounting to + 10 mgal and — 6 mgal exist at only 1.0 km distance with a sharp boundary. However, the positive area consists of older formations including the somma, Mts. Kurohu, Gippa and Kengamine and their atrio. On the other hand, the negative area includes the main part of the present Asama in which we find numerous alternations of pumice layers of small density. The somma mentioned above consists mainly of massive lava flows and tuffbreccia in compact state, and the rocks are chemically more basic than the recent ejecta. However, the Bouguer anomaly mentioned above was calculated by assuming density of the mountain to be the same. It is therefore necessary in studying the structure inside and beneath the volcano that correction be made by taking into consideration the density distribution of the upper part of the volcano. For this purpose, S. Aramaki is now investigating precisely the distribution of bulk density of this volcano, and his survey will be completed before long.

5. - Volcano Oo-sima (Mihara) 26) - 34)

As reported in the previous Bulletin, the 1950-1951 eruption of Oo-sima was of a large scale comparable to the 1777 eruption of this volcano. The 1951 eruption ceased completely towards the end of June 1951 and the volcano continued in a calm state up to October, 1953. However, on October 5, 1953 it resumed eruption of the Strombolian type in smaller scale, throwing bombs and scoriae from the 1951 crater. After that, several eruptions which lasted for several days or several hours occurred at longer intervals of quiescence. The mentioned state of activity continued until March 1954. Of the 1953-1954 eruptions, the one on January 27, 1954 was most remarkable on which occasion molten lava welled up and flowed to a depression in the inner somma. Since the volume of lava was not abundant, it did not overflow the inner somma.

The Oo-sima Weather Station, which is located 6 km to the north of the summit, conducted continuous seismometric observations by means of Wiechert seismographs. According to the result, no special seismic activity originating from the volcano appeared in this period except volcanic tremors caused by the present eruption.

T. Minakami and his associates studied volcanic tremors with highly sensitive seismographs which were fixed at two places on this volcano. After analyses of the seismograms, they

Table 7. - Record on the 1953-1954 eruption.
(After Oo-sima Weather Station)

Date	Locality	Remarks
1953		
Oct. 5	A craterlet newly formed on the 1951 crater.	At 8h 22m small eruption resumed with bombs and ash.
Oct. 6-12	»	Eruption continued with ebbs and flows and ceased at 12h 30m, 12th.
Nov. 9-13	Another craterlet opened in the 1951 crater.	A small cinder cone formed by continuous eruption. The eruption stopped at midnight 13th.
Dec. 1	The Nov. craterlet was enlarged.	Ash, bombs, scoriae were continuously ejected.
Dec. 8-19	The Oct. and Dec. craterlets were enlarged.	Incandescent bombs were abundantly ejected.
1954		
Jan. 1	»	
Jan. 3-9	»	
Jan. 11-16		A cinder cone nearly 50m high was newly formed.
Jan. 19	»	
Jan. 22	»	
Jan. 27	»	Molten lava overflowed the Oct. and Dec. craterlets, and the biggest blast in the present eruption occurred.

made clear that the natures of the volcanic tremors in this period were similar to those which appeared in the 1950-1951 eruption.

T. Rikitake and I. Yokoyama carried out frequently absolute measurements of the geomagnetic field at ten fixed points on the volcano since the 1950 eruption. From the comparison of these surveys, one made in June 1951 and the other in August 1953, they made clear that the intensity of magne-

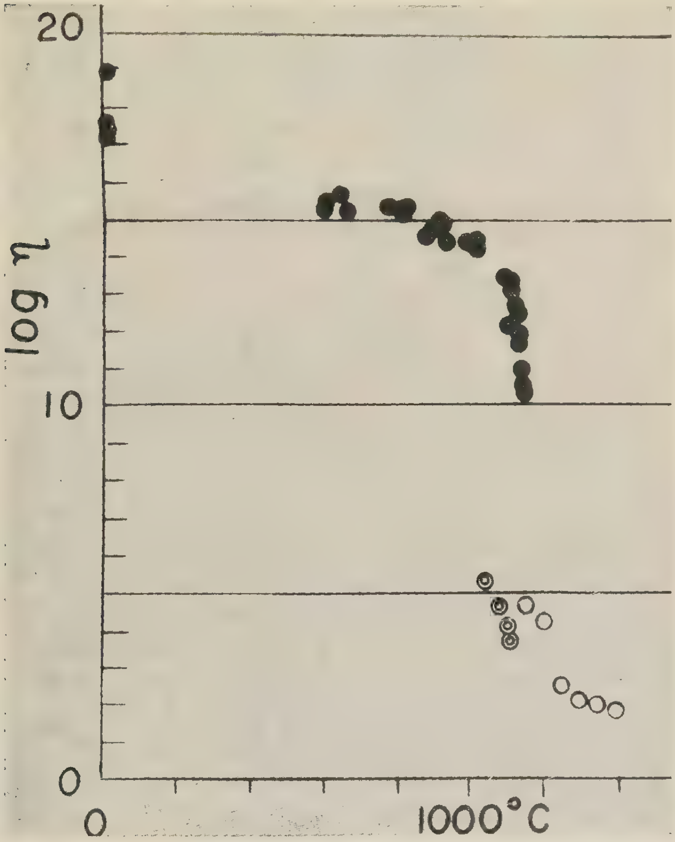

Fig. 13. - Viscosity coefficient of remolten lavas (in poises).
closed circle: result from Sakuma's experiment.
double circle: result from Minakami's experiment.
opened circle: result from Kani's experiment.
(After S. Sakuma, E.R.I.)

tization inside the volcano increased toward the direction of the present geomagnetic field and the amount of its variation was about 9 × 10^{13} e.m.u. However, the variation of the geomagnetic field in the period from July to Sept., 1950 showed the marked decrease of the magnetization of this volcano, of which the amount was estimated at 6 × 10^{14} e.m.u. On the other hand, continuous observation of the geomagnetic declination was made at the foot of the mountain, 4 km west of the summit from 1950. From the result of this observation also, they found that the magnetic intensity of this volcano decreased before and in the midst of the 1950-1951 eruption, and one tenth of it again approached the original state after the eruption.

Viscous and elastic properties of lavas are being studied by S. SAKUMA in the laboratory as well. Lava-specimens of various thermal history and of different crystallinity were examined at high temperatures. The lava-specimens were found to have been evidently affected by their respective thermal histories at time of solidification. It will be needless to say that systematic experiments concerning changes in the dynamical properties by heating in the laboratory give important clues to the mode of causation of these properties in the course of solidification. Therefore, it will be possible for us to estimate reasonably the properties of the actual lavas in molten state from the laboratory experiments, if the essential mode of development of the viscous and elastic properties is made clear by the experimental procedures. Some of the results on viscosity of the Oo-sima lava are illustrated on Fig. 13, together with those obtained in the field and those from the experiments made under a reasonable assumption for the rate of cooling in the field.

6. - Volcano Suwanose 35)

Suwanose island is located in the Ryukyu volcanic chain in which a number of active, dormant and extinct volcanoes are included. In the historical age, Suwanose erupted very frequently with Strombolian characters, though there appeared ebbs and flows in its intensity of activity.

On September 5, 1949, a strong earthquake was located in the neighbourhood of the volcano, and was followed by an almost continuous volcanic activity with little interruption up to the present (May, 1954).

According to S. MURAUCHI who investigated the eruption during October 1953, moderate eruption occurred every fifteen seconds on an average and ejected incandescent bombs to nearly 500 m distant from the summit crater. At the same time, he observed a number of micro-earthquakes accompanied with eruptions, and the anomaly of geomagnetic dip amounting to 2 degrees in arc. From the dip anomaly, the mean intensity of magnetization of the volcano was estimated at about 10^{-2} e.m.u./c.c.

7. - Miscellaneous Volcanoes 36) - 37)

1) Mt. Meakan-dake in Hokkaido (Lat. 43° 32' N, Long. 144° 02' E).

People living at the north eastern and eastern villages of Mt. Meakan-dake felt frequently severe but local shocks and heard sometimes rumblings from the mountain during the period from July 31, 1951 to March 1952. Especially, the 200 earthquakes on July 31, 1951 and the 400 ones on March 4, 1952, showed the most remarkable seismic activity. However, it is interesting to note that the latter swarm of shocks took place simultaneously with the Tokati earthquake of great magnitude, of which the epicenter was estimated to be in the sea, about 180 km from Mt. Meakan. Although these earthquakes swarms of Mt. Meakan were believed to originate from the shallow depth under this volcano, no conspicuous volcanic activity appeared up to April, 1954.

2) Mt. Yakedake in Central Japan

From July 1953, local earthquakes were felt at the eastern foot of the mountain. Since this volcano erupted strongly in 1907-1915, the people in the vicinity of the volcano feared lest it might erupt as in the former case. T. MINAKAMI and his associates made seismometrical investigation with sensitive seismograph. As the result, they observed micro-earthquakes of shallow depth originating from the north-eastern foot of the volcano. But, the mountain did not show any volcanic activity.

3) Mt. Bandai

On April 3, 1954, landslides of moderate scale took place at the margin of the explosion crater which was made by the furious explosion in 1883. According to brief investigation made by S. Suwa, the present landslides were of ordinary one, independent from the volcanic activity of this volcano.

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PLATES

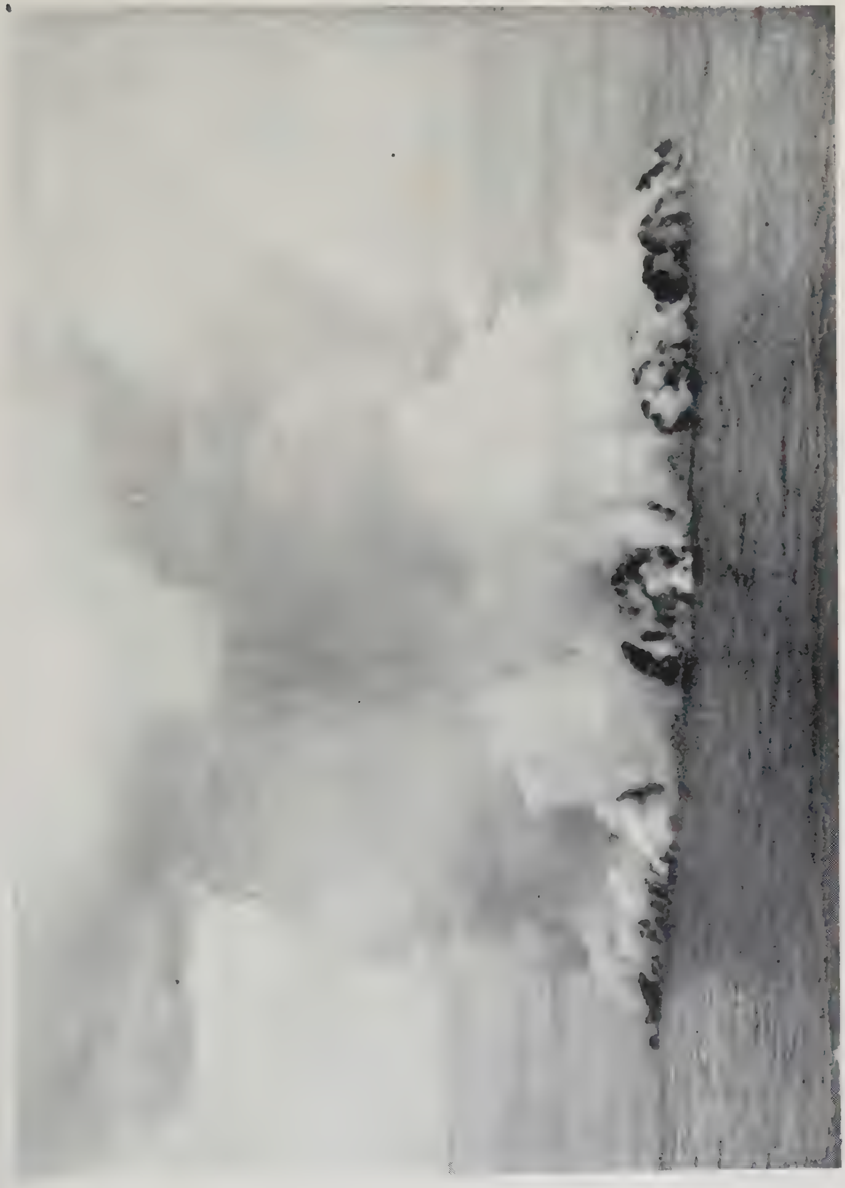

Fig. 14. The eruption of Myozin-syo on Sept. 18, 1952 (After T. MINAKAMI, E.R.I.)

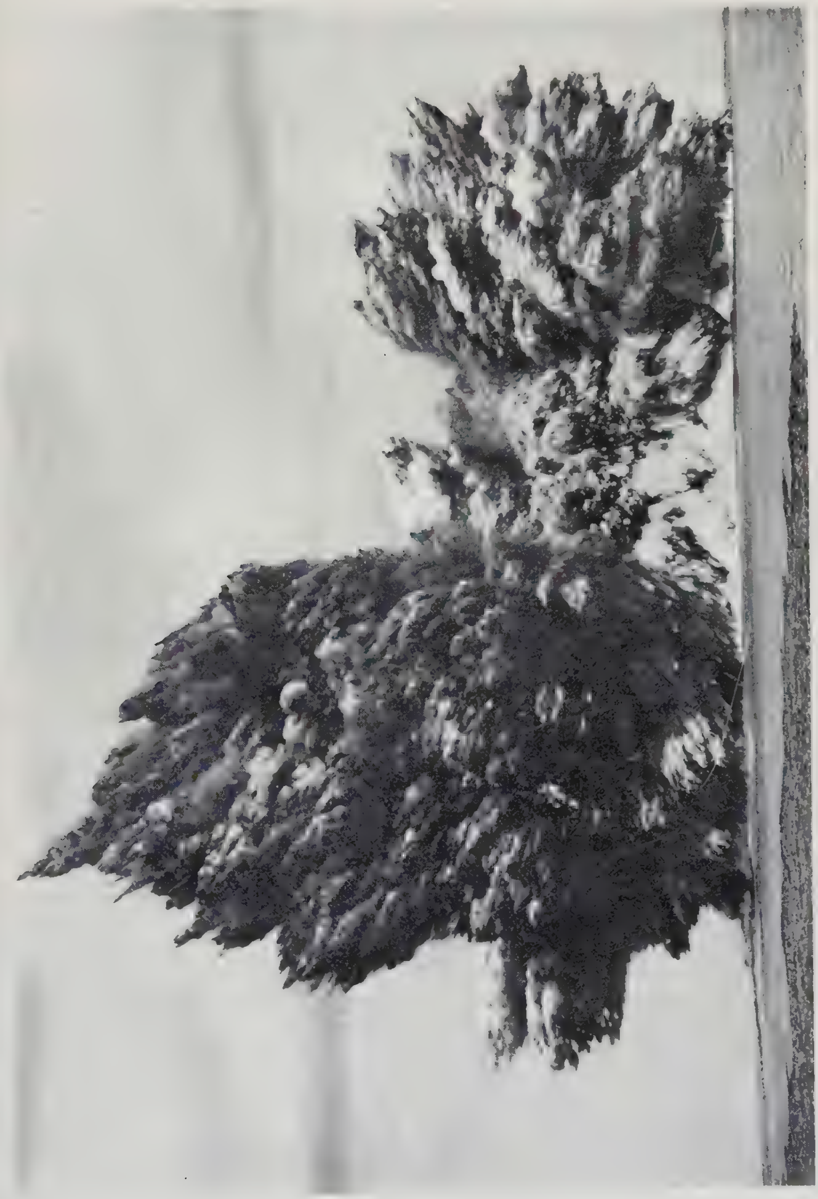

Fig. 15. - The submarine eruption of Myozin-syo on Sept. 23, 1952.
(After A. SUGANO, Asahi Shinbun)

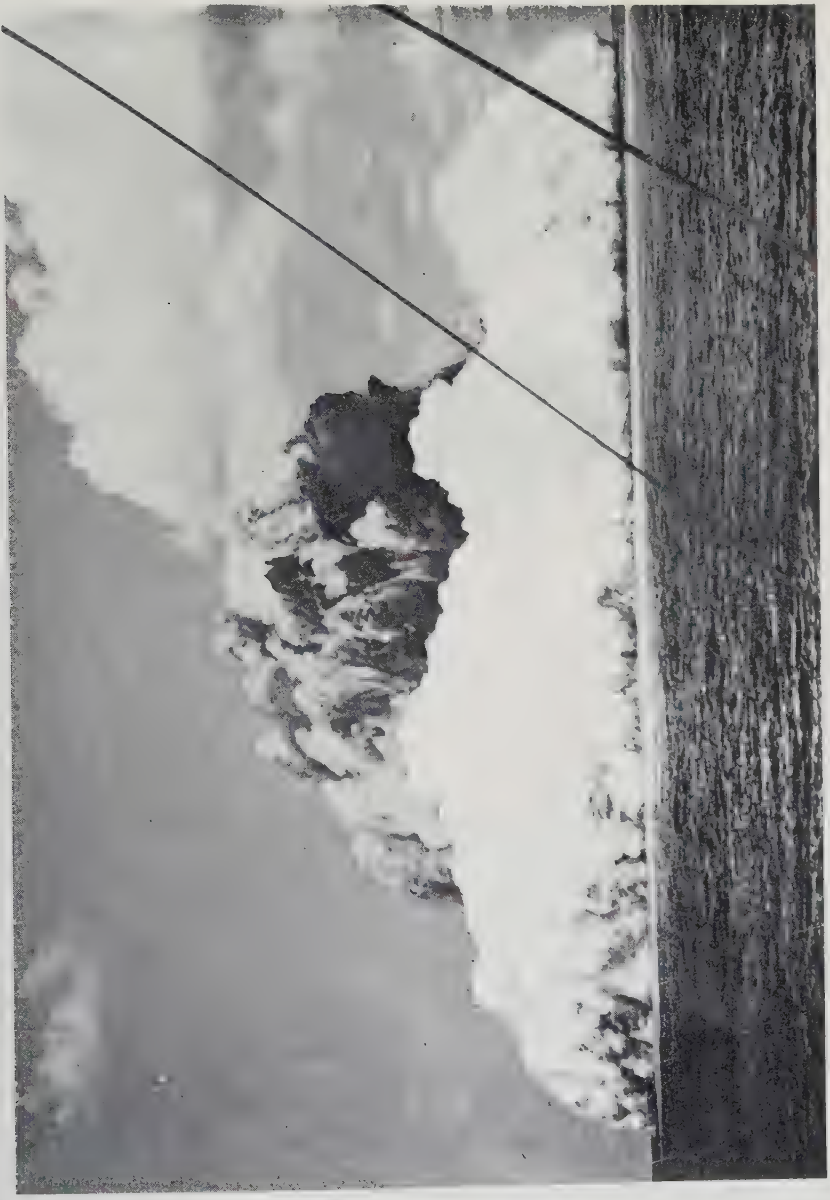

Fig. 16. - The submarine eruption of Myozin-syo on Sept. 23, 1952.
(After A. SUGANO, Asahi Shinbun).

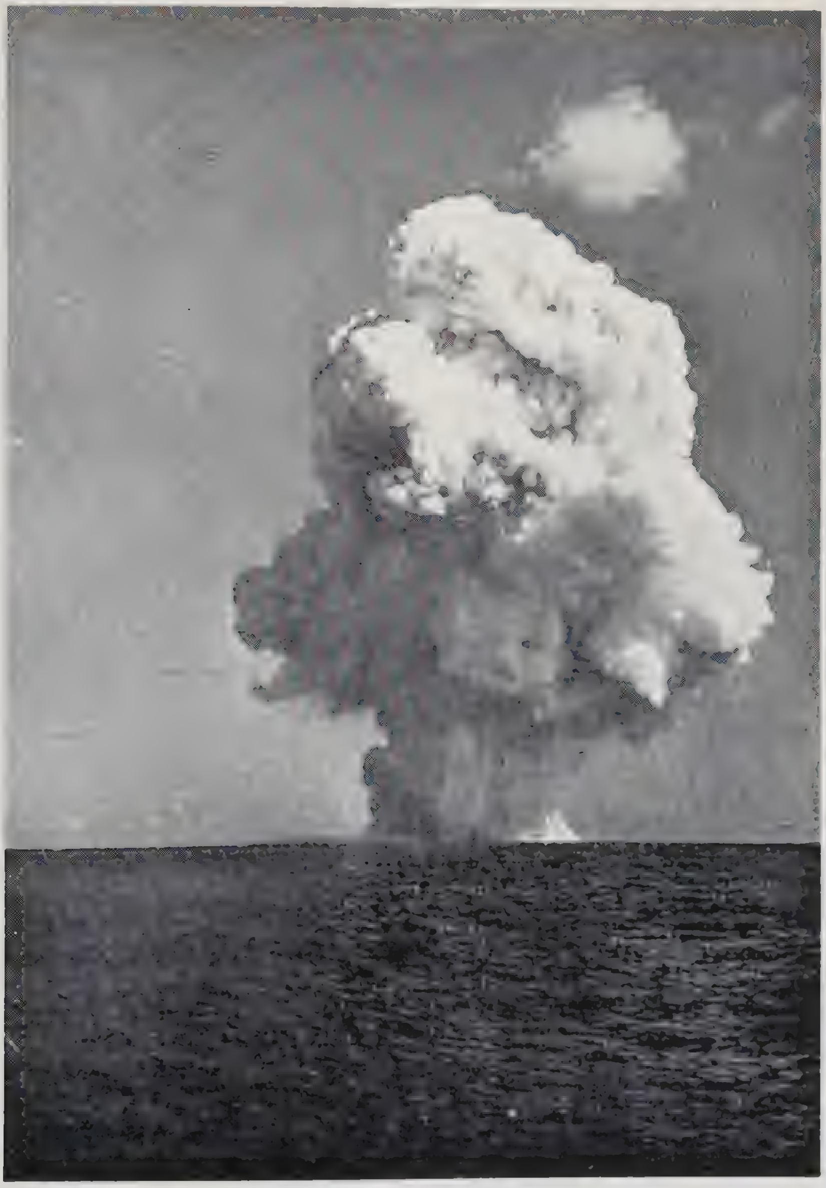

Fig. 17. - The submarine eruption of Myozin-syo on Sept. 23, 1952.
(After A. Sugano, Asahi Shinbun)

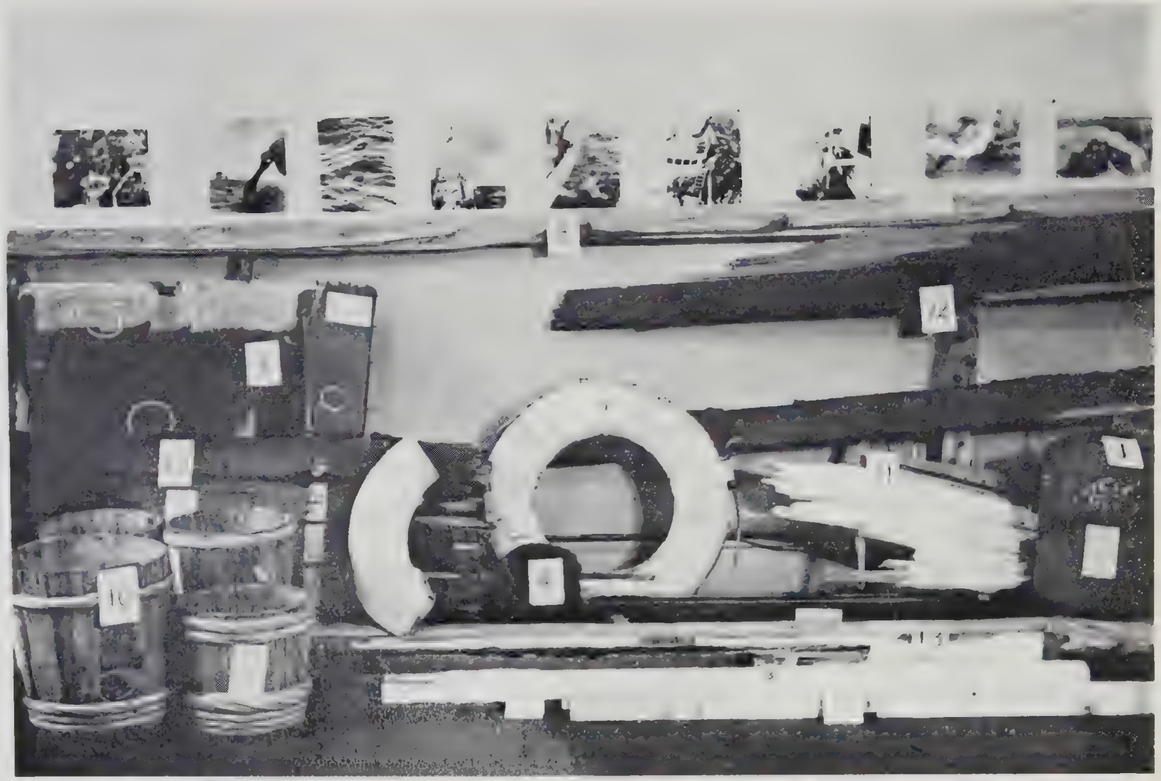

Fig. 18. - The floating materials from the Kaiyo-maru No. 5
(After the Hydrographic Office)

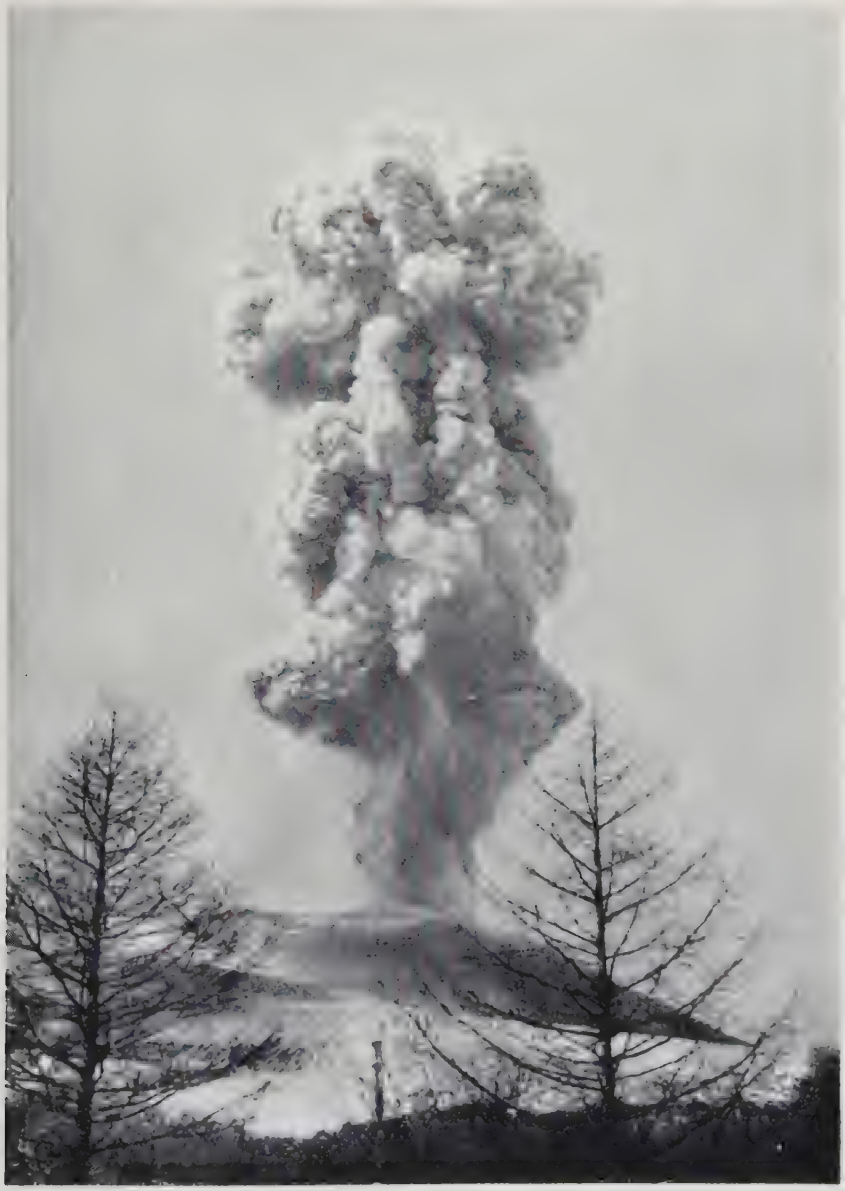

Fig. 19. - The small eruption of Mt. Asama on January 12, 1954.
(After S. UCHIBORI, E.R.I.)

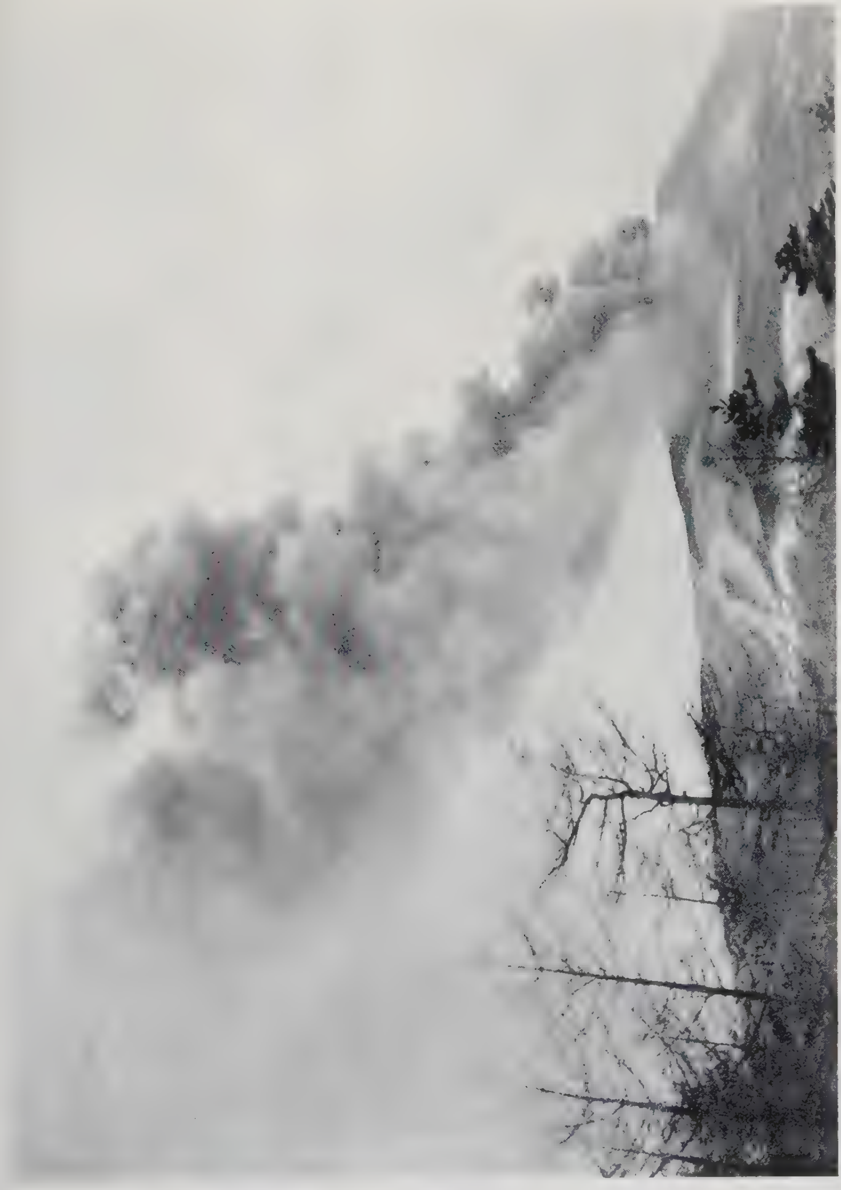

Fig. 20. - Small eruption of Mt. Asama.
(After S. UCHIBORI, E.R.I.

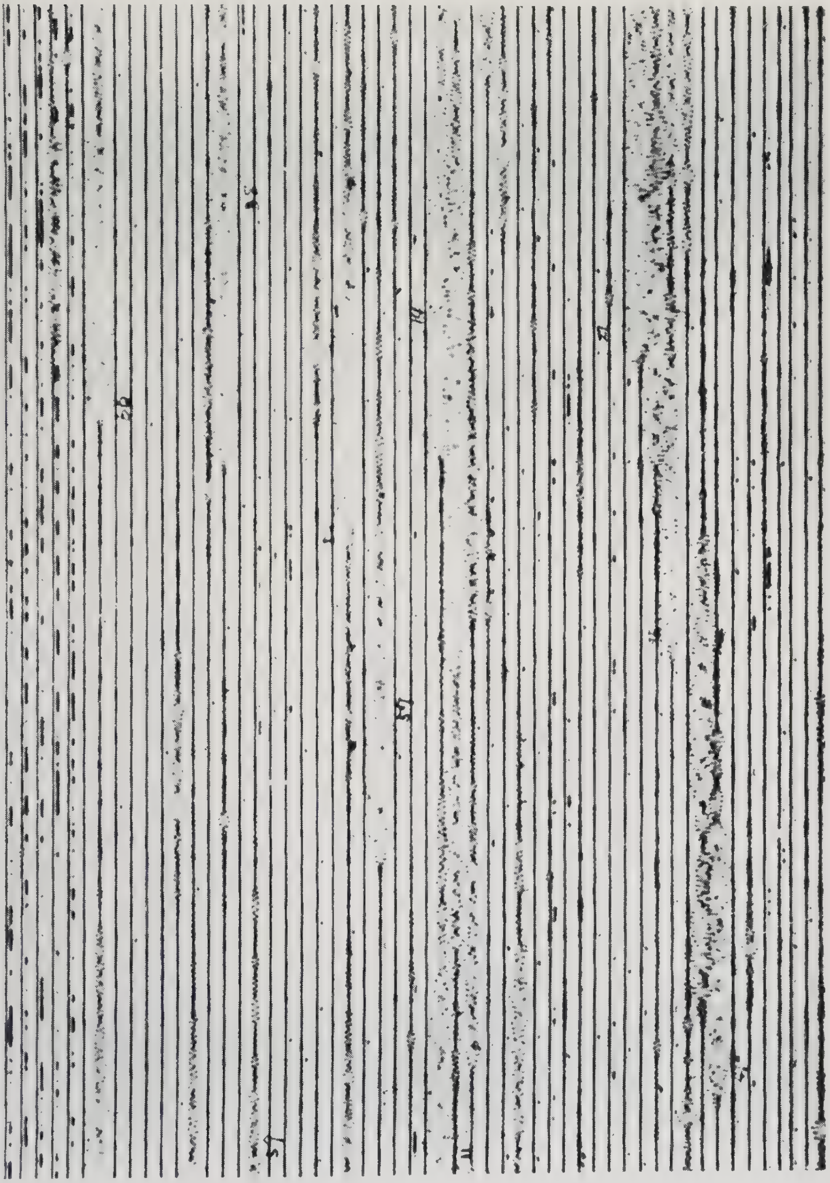

Fig. 21. - Seismogram of micro-earthquakes originating from Mt. Asama
(After T. Minakami and his associates, E.R.I.)

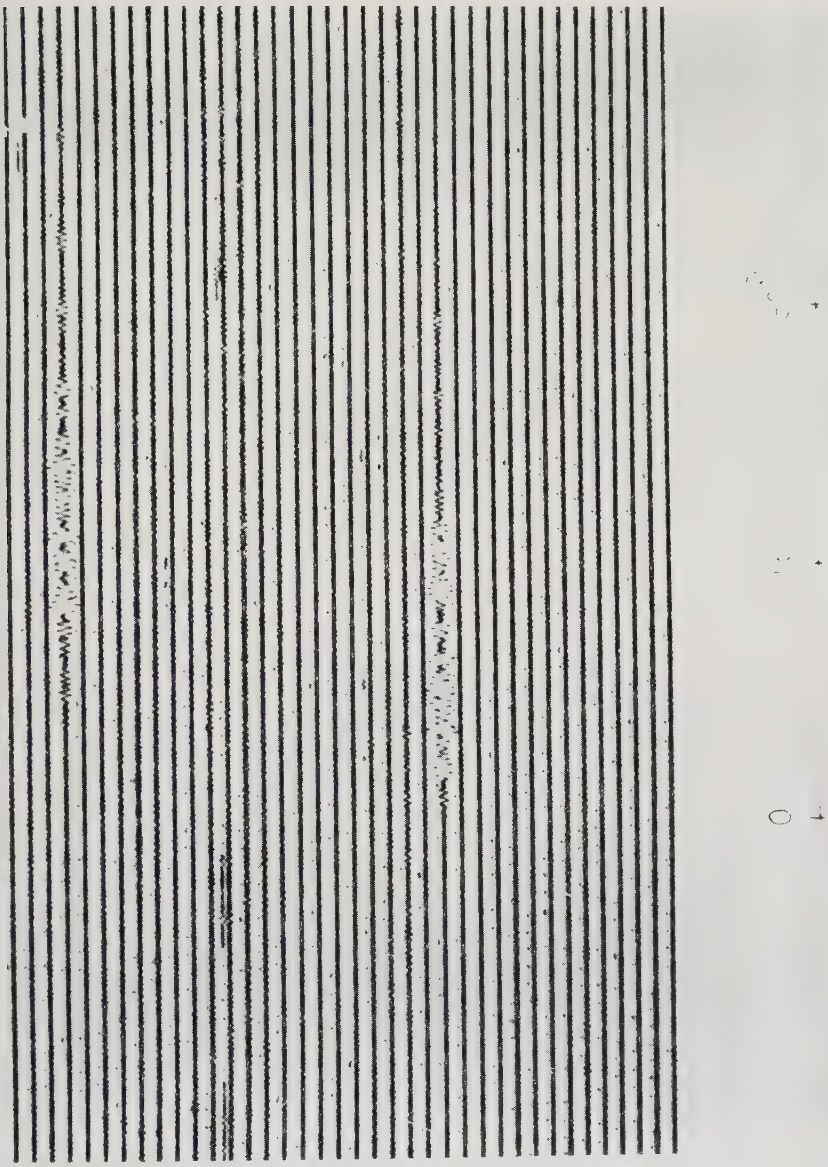

Fig. 22 - Sismogram of micro-earthquakes originating from Mt. Asama. (After T. MINAKAMI and his associates, E.R.I.)

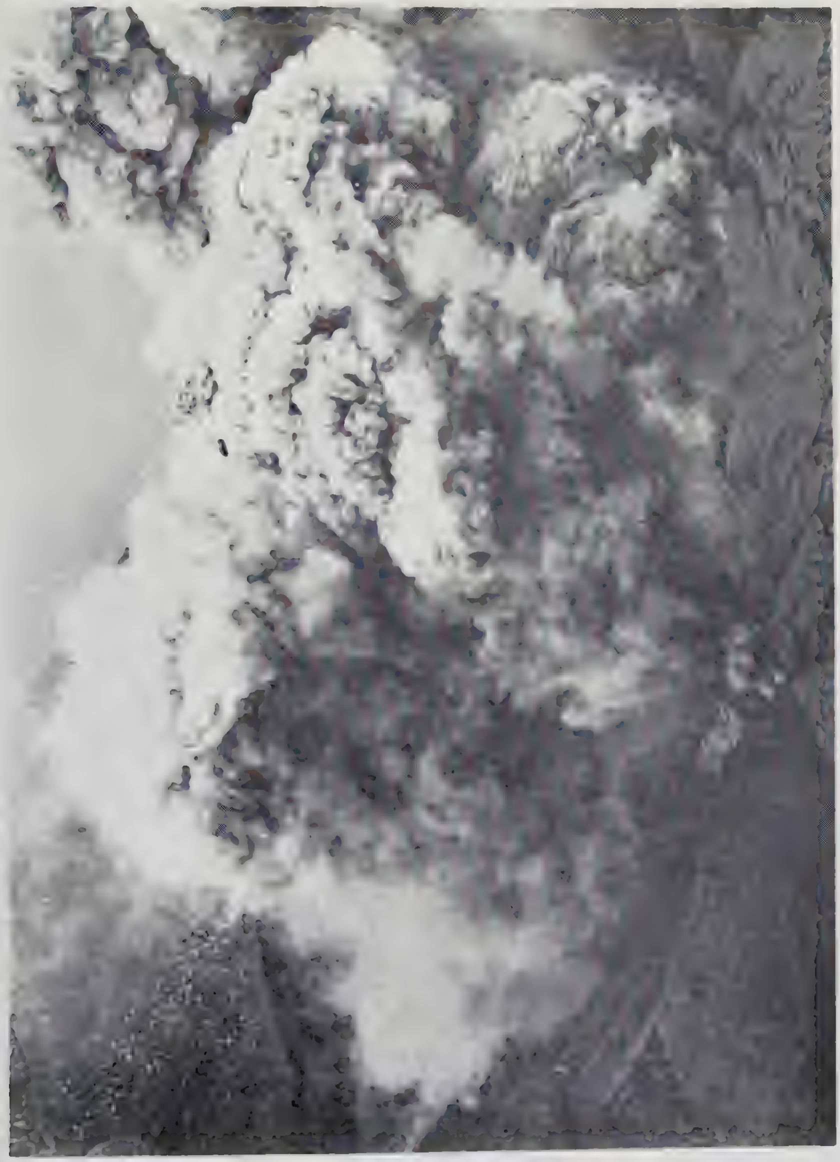

Fig. 13 The minor eruption of Suwanose on October 10, 1953.
(After S. MURAUCHI, Natur. Sci. Mus.)

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On Magnetization of Mt. Fuji (Huzi) and Other Volcanoes in Japan.

(With 13 text-figures and 1 plate)

1. Introduction

In recent years, the remarkable anomalies in the geomagnetic field on and around the volcanoes have attracted attentions of many geophysicists and geologists.

In order to throw light upon the phenomenon, precise magnetic surveys of various volcanoes have been made for the last twenty years in Japan. As the result, it was found that active and dormant volcanoes in Japan are magnetized approximately towards the north by the induced magnetism of the present geomagnetic field and by the remanent magnetism of ejected materials. In addition, it was elucidated that the magnetic intensity of a volcano depends remarkably on the petrographical and physical properties of the rocks composing it. In general, intensity of magnetization of a basaltic volcano is several times that of andesitic one.

On the other hand, experimental studies of magnetic properties of various volcanic and other rocks were made by several geophysicists. Among them, T. NAGATA 1) has been studying actively the magnetic properties of rocks in the laboratory from view-points of physics and geophysics.

Magnetic properties of volcanic rocks are ascribed to the ferromagnetic minerals in them. The total magnetization is divided into two parts, $\vec{J} = \vec{J_n} + \vec{KH}$. One is the induced magnetization ($\vec{KH}$) and the other is the remanent one ($\vec{J_n}$). The remanent magnetization is acquired when the lava cools down below the Curie-points of constituent ferromagnetic minerals and it is stronger than the induced one in most cases.

The writers observed various phenomena by many geomagnetic surveys of volcanoes in Japan. The research works are summarized from volcanological stand-points in this paper.

2. Magnetic Survey of Volcano Huzi

Mt. Huzi is not only the most beautiful and famous mountain in Japan, but it is also one of the most perfect and symmetric strato-volcanoes in the world 2).

In 1898, the late A. Tanakadate 3) made a magnetic survey of Mt. Huzi. He measured the geomagnetic three elements on the summit, on the flank and at the foot of the volcano. However his survey was not sufficient in number to discuss the geomagnetic anomaly in detail.

Forty years after Tanakadate's survey, one of the writers planned a resurvey of the Huzi volcano, in which he aimed to study the geomagnetic anomaly due to the magnetization of the volcano.

For this purpose, the spots, where magnetic observations were made, were chosen carefully so as to be distributed evenly not only on the summit but also on the flank and at the foot of the volcano.

The present magnetic survey of Huzi was made in the summers of 1941-1943. The three elements of geomagnetic field, namely, horizontal intensity (H), declination (δ) and dip (I) were measured at 71 spots in total, and at some spots only one or two elements were measured as follows:

Elements	Number of spots
H. δ, I	34
H, I,	22
H	3
I	12

In the present observations, the instrument of electromagnetic type was used in most of the observations, though a dip-circle and a magnetometer of vibration type for horizontal intensity were also utilized as auxiliary instruments for observations at steep topography.

Errors of observations by the electro-magnetic method are ±1γ, ±0.1′, and ±0.1′ respectively for the three elements.

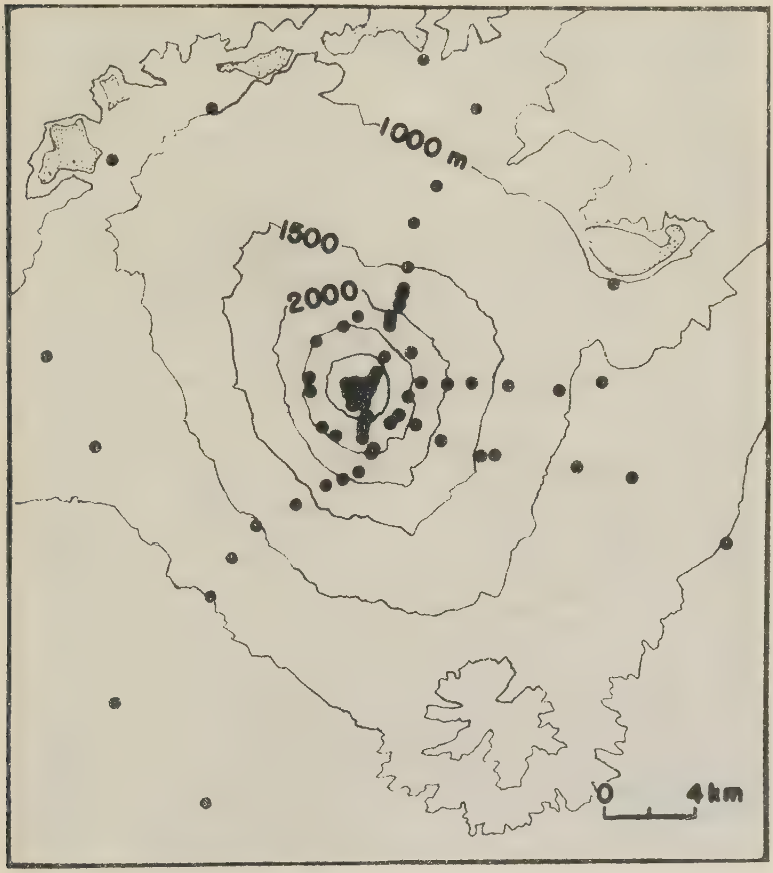

Fig. 1. - Geographical position of the spots where geomagnetic observations were made.

While, those of the dip-circle and vibration apparatus are ±3′, and ±10γ respectively.

The geographical positions of the spots are shown on the map of Fig. 1.

On the other hand, the standard values of the three elements of the geomagnetic field for the latitude and longitude of these observed spots were calculated from the experimental formula of the geomagnetic field which the Hydrographic Department had obtained by magnetic surveys throughout Japan. Therefore, the anomalous values of the three elements were determined by subtracting these normal values from the observed ones.

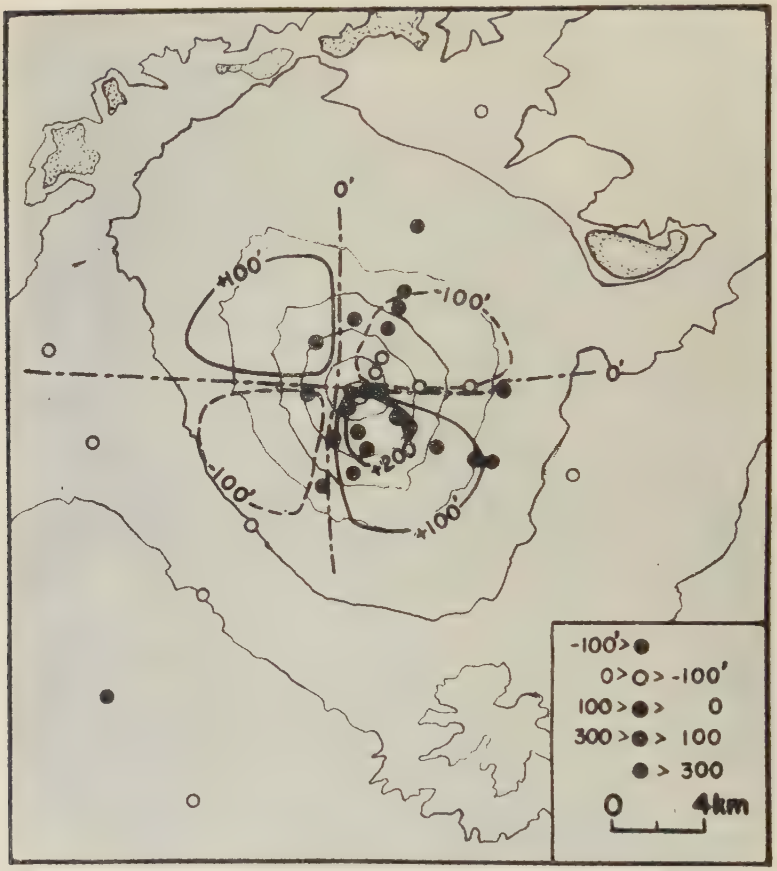

Fig. 2. - Anomalous distribution of declination on and around Mt. Huzi (Fuji).

The geographical distribution of these anomalous values of three kinds, obtained by the above-mentioned procedure, are illustrated on the map of Figs 2-4. Maximum values are about 15⁰ in declination, 10⁰ in inclination and 3000 γ in horizontal intensity.

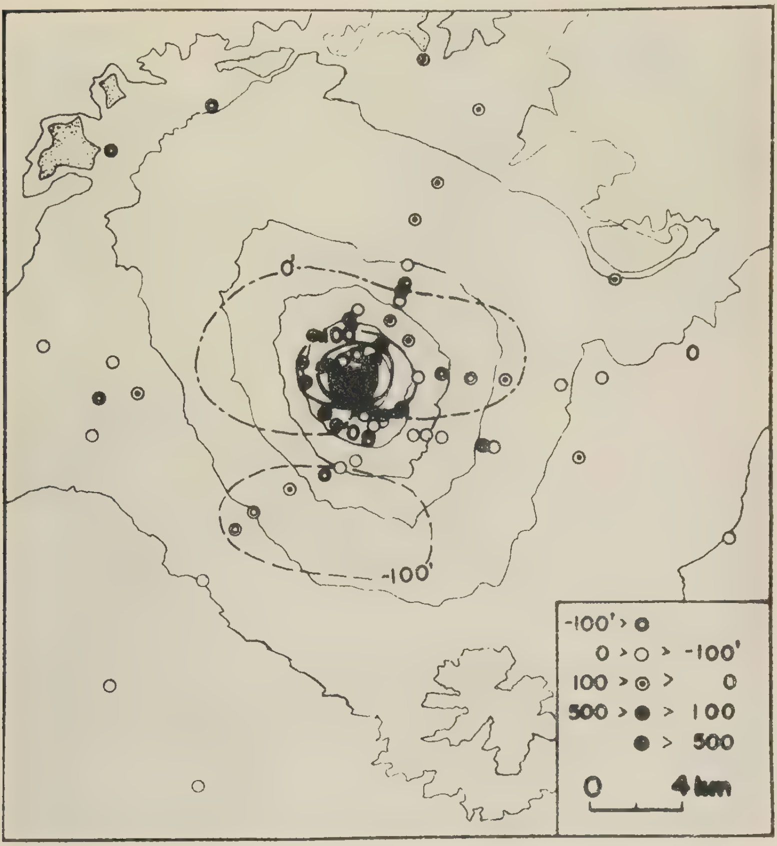

Fig. 3. - Anomalous distribution of dip on and around Mt. Huzi.

At a glance of these maps, it will be clear that the magnetic anomaly on and around Mt. Huzi is not only very remarkable in amount but also systematic in its geographical distribution, which may be due to the magnetization of the volcano itself.

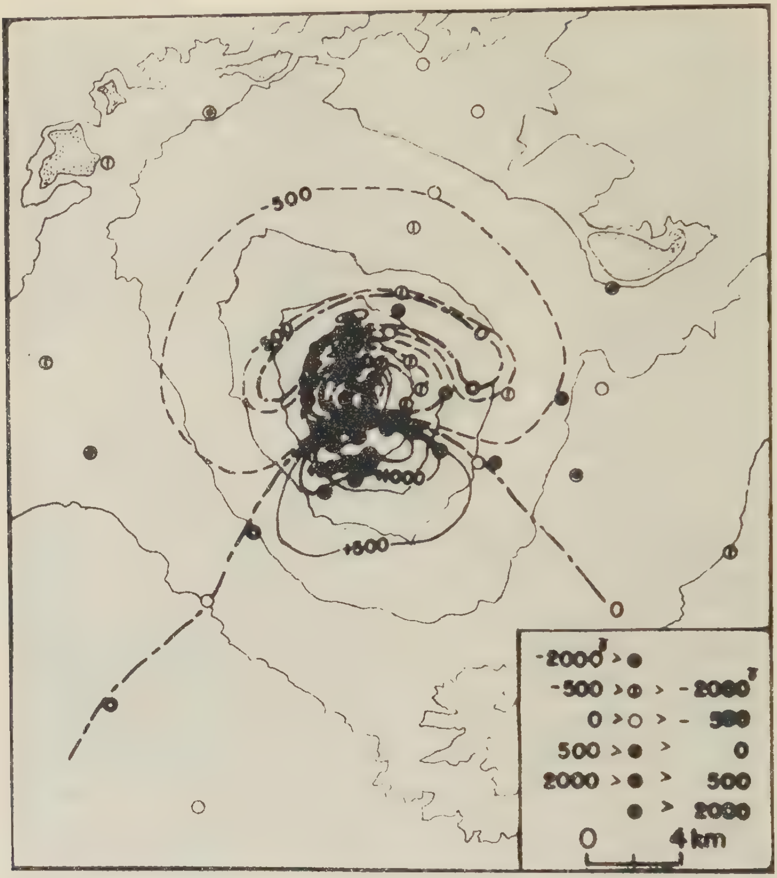

Fig. 4. - Anomalous distribution of horizontal intensity on and around Mt. Huzi.

3. Magnetization of Volcano Huzi (Fuji)

J. Bahurin, H. Haalck, P. Lasareff, J. Koenigsberger 4), T. Nagata, the writers and other investigators have studied the geomagnetic field due to the magnetization of materials of some sample.

The contour-lines of Mt. Huzi form almost concentric circles with the crater as a centre, and it is possible to put four oblate ellipsoids one on top of the other so that they conform approximately to the shape of the volcano. For convenience of mathematical treatment, calculation was made by the Haalck-Koenigsberger's method in which those ellipsoids are assumed to be homogeneously magnetized.

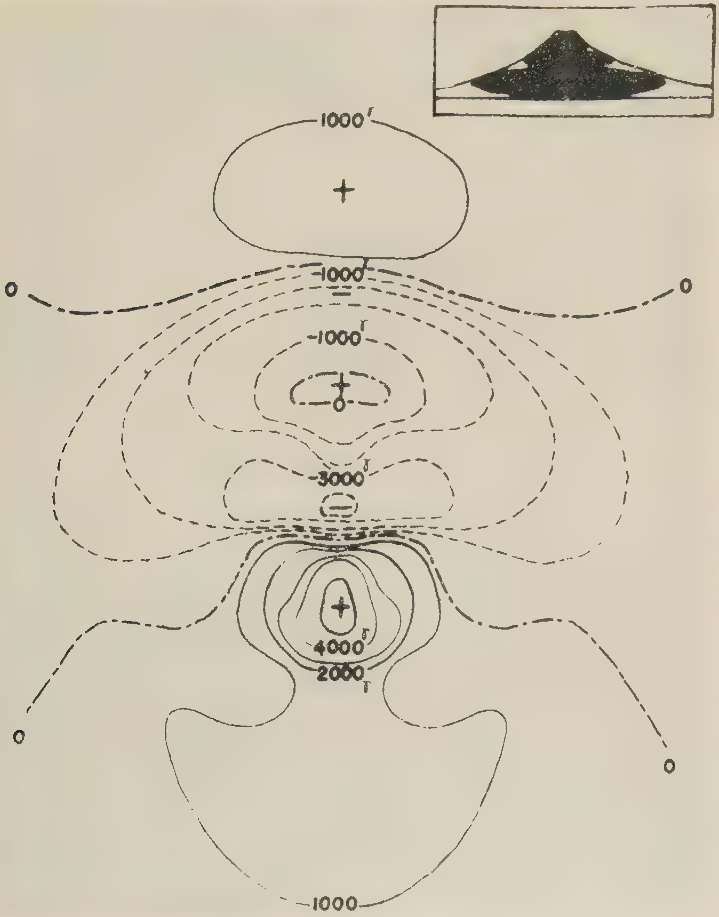

Fig. 5. - Calculated anomaly of horizontal intensity.

It was our purpose to find the intensity and direction of magnetization of the volcano which agrees best with the actual anomaly. In the present survey, the observations of horizontal intensity were made frequently and precisely, and this element was used for the purpose.

For instance, Fig. 5 shows the geographical distribution of horizontal force caused by the ellipsoids homogeneously magnetized towards the astronomical north, in which intensity and inclination of magnetization are 10^{2} e.m.u. and 50° respectively.

In order to obtain the azimuthal direction of magnetization of the volcano, the absolute values of the differences between the observed and the calculated horizontal intensity are summed up for all the observation spots (59 in number).

This procedure is carried out for every five degrees with respect to the direction of magnetization, that is N, N5°W, N10°W, - - - N10°E, N5°E. The azimuth where the above-mentioned sum is minimum shows the azimuthal direction of the magnetization of the volcano.

It is needless to say that these procedures are carried out not only for various intensities but also for various inclinations. At least, it is concluded from these calculations that Volcano Huzi is magnetized towards N7°W in azimuth, 50° in inclination and 3×10^{-2} e.m.u. in intensity on the average.

However, as may be seen in the geographical distribution of anomaly of Mt. Huzi (Figs. 2-4), the extremely large anomaly is located near the summit only. Accordingly, it may be said that the result of such investigation made by means of minimum deviation is affected unduly by the values observed on the summit. On account of this reason, the problem is reviewed by another method, in which the relation between the observed and the calculated values is examined by means of coinsidence of signs between the observed and the calculated values, namely, positive and negative.

Judging from this calculation also, we may reasonably conclude that magnetization toward N7°W determined by the foregoing method is true as to the azimuthal direction of magnetization of Volcano Huzi.

The average intensity of magnetization 3×10^{-2} e.m.u. obtained here harmonizes well with that of remanent magnetism of lava-specimens which were studied by T. Nagata. Accordingly, it may be said that the geomagnetic anomaly of Mt. Huzi is seriously affected by natural remanent magnetism of lava-flows which compose the volcano.

The fact that the remanent magnetism of lava-flows on the surface of Mt. Huzi is magnetized approximately towards the present geomagnetic field shows that the geomagnetic direction at the time of their ejection could not have deviated largely from the present one. On the other hand, it must not be neglected that the direction of magnetization of the volcano thus determined is affected by the induced magnetism.

Moreover, if some of the lava-flows was magnetized towards north-east and the other towards north-west, the average magnetization of the lava-flows will be, in the statistical investigations, approximately towards the north.

4. Outline of Geomagnetic Studies of Other Volcanoes

Mt. Huzi is a typical cone and is composed of basalt. Geomagnetic anomaly near volcanoes of different rocks and of various structures is an interesting problem.

In order to study the magnetic anomalies of the volcanic regions, geomagnetic surveys of volcanoes in Japan were carried out as follows.

1) Oo-sima (basalt)

The three elements of the magnetic field of Volcano Oo-sima (Mihara-yama) were measured at 12 spots in 1937 by R. Takahasi and T. Nagata 5) and at 10 more spots in 1951 by T. Rikitake and others 6).

T. Rikitake showed that the anomalous distribution of magnetic field of the Oo-sima volcano can be reasonably explained by magnetic disturbing force caused by its magnetization nearly in the north direction. T. Rikitake measured the geomagnetic dip at 36 spots on the volcano and estimated its mean magnetization at 0.03 e.m.u.

2) Volcano Oomuro (andesite)

T. Nagata and K. Hirao 7) made the survey of three elements of the geomagnetic field of Mt. Oomuro. From the result of this survey, they concluded that the geomagnetic anomaly on and near the volcano agreed with the anomaly due to its magnetization to the present magnetic-north.

3) Volcano Asama (andesite)

The magnetic survey was conducted by one of the writers in the period during 1937-1939. At first, in 1937 8), he observed the magnetic dip at 80 spots in the neighbourhood of the summit crater, midway to it, and at the foot of the volcano. In the survey in 1938 and 1939 9), he measured the three elements of the magnetic field on and around the volcano.

On the basis of the result of the survey, the geomagnetic anomaly of the volcano was obtained by the same procedure as in the case of Volcano Huzi.

And it was made clear that the Asama volcano is magnetized almost in the direction of the present geomagnetic field, i.e. N5°W. Its intensity of magnetization was estimated at about 2.2×10^{-3} e.m.u., which is about one-tenth of that of Huzi.

4) Volcano Sakura-sima (andesite)

According to the magnetic surveys of Sakura-sima, where the declinations around the foot were observed by Y. Harada 10) and the dips were measured by one of the writers 11), anomalous distribution of the magnetic field showed the magnetization of the volcano to be towards the north, and its intensity was estimated at about 1.8×10^{-3} e.m.u. by one of the writers.

5) Mae-yama (andesite)

W. Yoda 12) carried out a survey of the three elements of the geomagnetic field at 87 spots around this volcano in

1923 and 1951. On the basis of the anomalous distribution, he concluded that the Mae-yama volcano is magnetized approximately toward the north. Intensity of magnetization is not so large as that of Mt. Huzi.

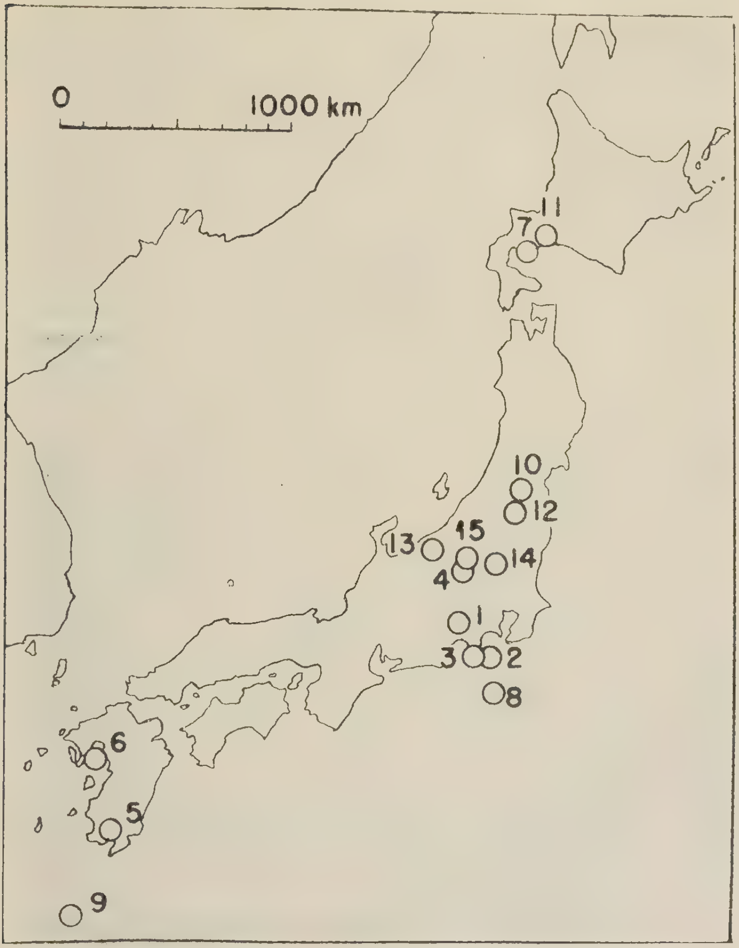

Fig. 6. - Geographical position of volcanoes, in which geomagnetic survey was made.

1, Huzi 2, Oo-sima 3, Oomuro 4, Asama 5, Sakura-sima 6, Mae-yama 7, Usu 8, Miyake-sima 9, Suwanose-sima 10, Zao 11, Tarumai 12, Azuma 13, Yakeyama 14, Akagi 15, Kusatu-Sirane.

6) Volcano Usu (andesite somma, dacite dome)

T. Nagata 12) and his associates measured the three geomagnetic elements at 21 spots on and around the volcano in 1943 and 1944. The distribution of the anomalous geomagnetic field nearly agrees with the mode of the anomaly around other volcanoes, though the direction of mean magnetization seems to deviate westerly by about 40^0 from the present magnetic north.

7) Surveys on other volcanoes

Because the survey of the dip inclination is the easiest, many other volcanoes were studied concerning the anomalies in dip. They are Miyake-sima (basalt) by T. Minakami 14), T. Takahasi and K. Hirano, Suwanose-sima (andesite) by S. Murauchi, Zao (andesite) by Y. Kato 15), Tarumai (andesite) by S. Sakuma, Azuma-yama (andesite) by T. Minakami 16), Yake-yama (andesite) by S. Sakuma and T. Minakami, Akagi (andesite) by T. Rikitake 17), and Kusatu-Sirane (andesite) by T. Minakami 18). These volcanoes showed anomalies in inclination without exception. The anomalies can be explained satisfactorily by magnetization of volcanic bodies in the direction of the present geomagnetic field. The intensities of magnetization are various but not unsystematic. This will be discussed later.

5. Magnetization of New Lavas in the Form of Flow or Dome

At the occasion of two recent volcanic eruptions, Miyake-sima in July, 1940 and Sakura-sima in April, 1946, which were accompanied by ejection of new lava-flows, the writers measured the geomagnetic dip near the lava-flows. That is, at Miyake-sima one of the writers 19) repeated the measurement at the same positions to know how magnetization develops when the fluidal aa-flow cools down, and at Sakura-sima a dip-survey was carried out 20) on and by the side of the new lava-flow of block type to study the geomagnetic anomaly.

1) Development of magnetization with time

In Miyake-sima, at 1 km distant from the new lava, change in dip was less than 5′ from Aug. 3, 1940 to May 16, 1941, while at A, 6 m north of the Akabakyo lava-flow, it decreased 1° 09′ from Aug. 3, 1940, to May 16, 1941, and at Y, 3 m south of the Yoridai-sawa lava-flow, 1° 22′.7 from July 28, 1940, to May 16, 1941 (Fig. 7, Fig. 8). In addition to that, the rate of decrease in dip diminished rapidly, namely, changes of magnetic field became smaller and almost ceased in the next year (1941).

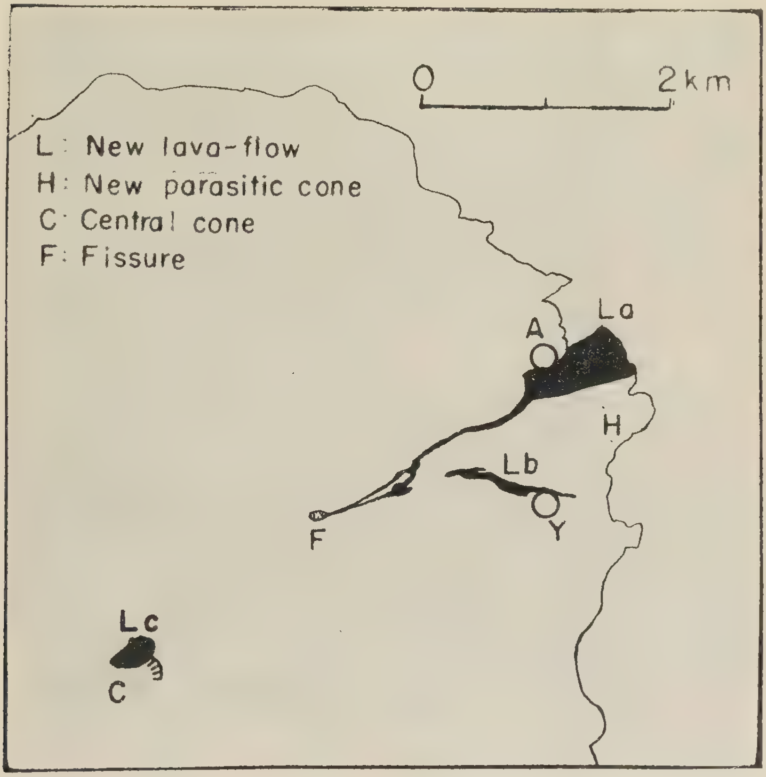

Fig. 7. - Lava-flow and observation spots at Miyake-sima.

The temperature near the surface of the lava in July was

900°C-1000°C, and exceeded the Curie-point of the rocks. In May, 1941, the Akabakyo lava-flow cooled down within 2 m from its surface, and the Yoridai-sawa lava-flow which is smaller in volume must have cooled more rapidly.

An estimation of intensity of magnetization (J) is made on the assumption that the Yoridai-sawa lava-flow was uniformly magnetized to the direction of the present geomagnetic field, and we get J = 0.012 e.m.u. This agrees fairly well with the natural remanent magnetization given by NAGATA's experiment. Consequently, we may well conclude that the change of the geomagnetic field mentioned above is due to the thermo-remanent magnetization of the cooling lava-flows.

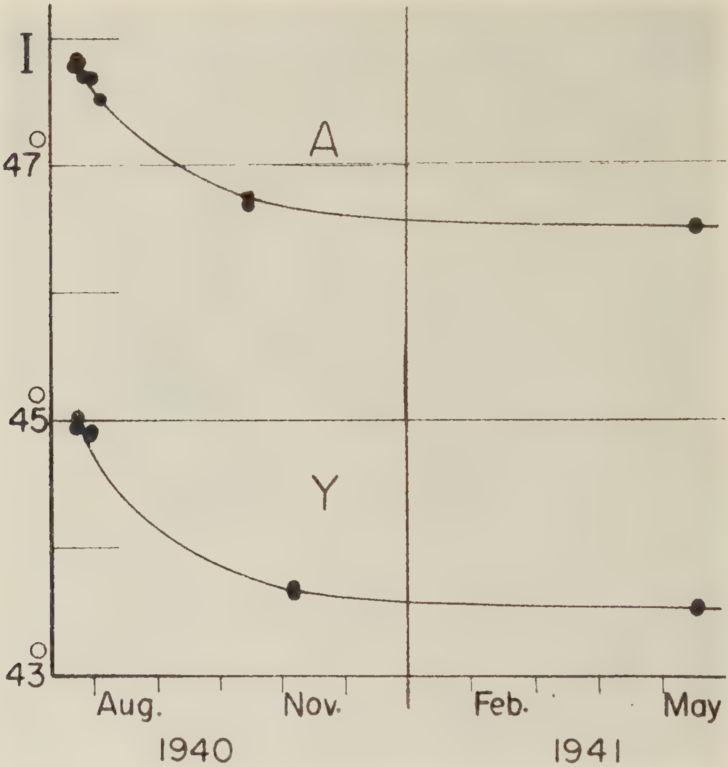

Fig. 8. - Variation in dip near the 1940 lava flows of Miyake-sima. A); at spot A, in Fig. 7. Y); at spot Y, in Fig. 7.

2) Anomaly due to new lava-flows

In Sakura-sima, we measured the geomagnetic inclination at the observation-spots of 1939 again in the southern half of the island in October of 1946 the year of eruption, and found that no remarkable change in dip had took place since 1939 at all observation-spots except one situated quite near the new lava-flow. Therefore, another survey of dip was carried out across the northern margin of a branch of the new lava-flow. The branch ran westwards along the old lava-flow ejected in 1914 (Taisyo lava) and is about 30 m high and 50-100 m wide. As the result of this survey, a remarkable anomaly was observed, that is, contours of dip ran parallel with the northern margin of the lava-flow as shown in Fig. 9. This kind of anomaly can be explained well by assuming that the lava is magnetized to the direction of the present geomagnetic field.

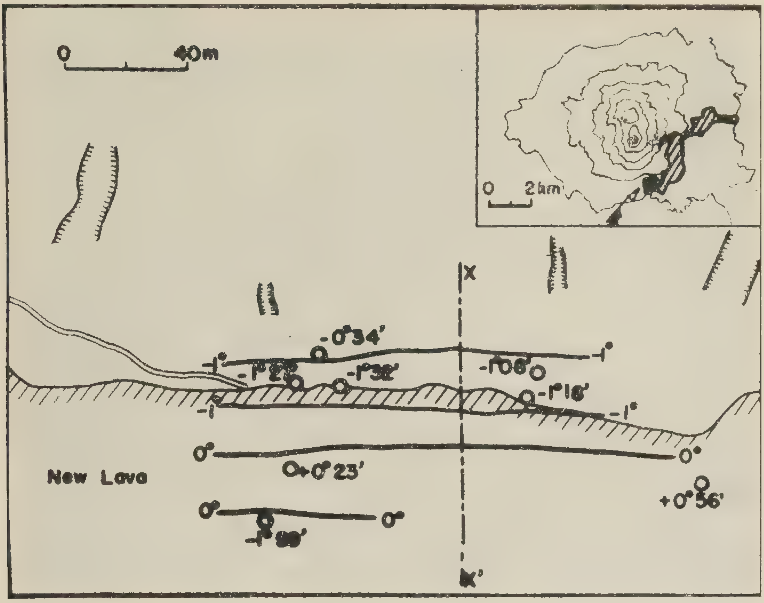

Fig. 9. (a) - Geomagnetic anomaly (dip) due to magnetization of the 1946 lava-flow in Sakura-sima.

Intensity of magnetization was estimated at 0.005 ± 0.001 e.m.u., which is nearly the same as the figures obtained by NAGATA in the laboratory.

On the lava-flow, however, observed dips were smaller than calculated, especially near the boundary to the older lava. If we regard the boundary region of the old and new lava-flow as non-magnetic on the average, we acquire a curve quite similar to the observed anomaly (Fig. 9). It is not unreasonable to infer that mechanical disturbance at the boundary of the older lava and the flowing block-lava resulted in random rotation of the already magnetized rocks and caused the magnetic « cavity » on an average.

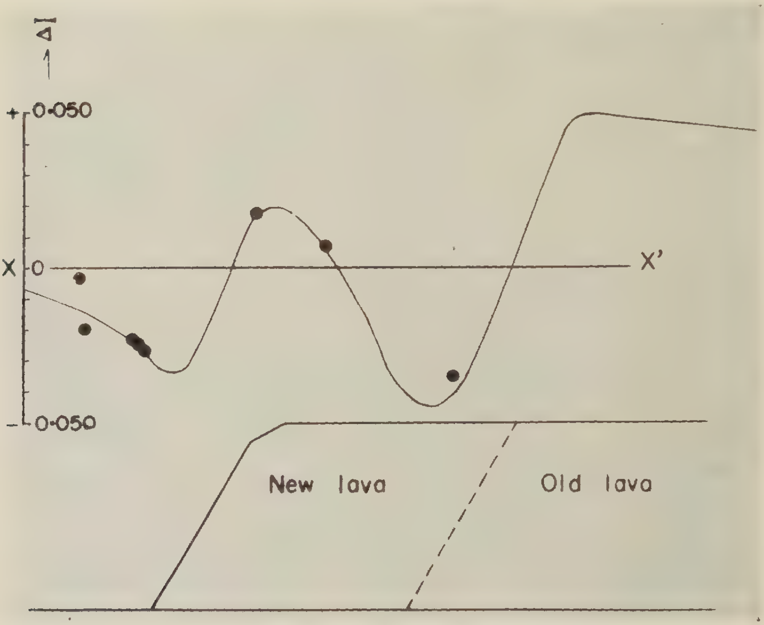

Fig. 9. (b) - Geomagnetic anomaly (dip) due to magnetization of the 1946 lava-flow in Sakura-sima.

3) Magnetic anomaly due to a lava-dome

Those volcanoes which squeeze out their lavas in the form of a dome or a spine differ remarkably in their character of volcanic activities as well as in petrographical properties from those which issue lavas in fluidal form, such as Oo-sima and Miyake-sima. The magnetic anomaly on and around the lava-dome of Volcano Tarumai was studied by one of the writers in 1953. The dome was built up during

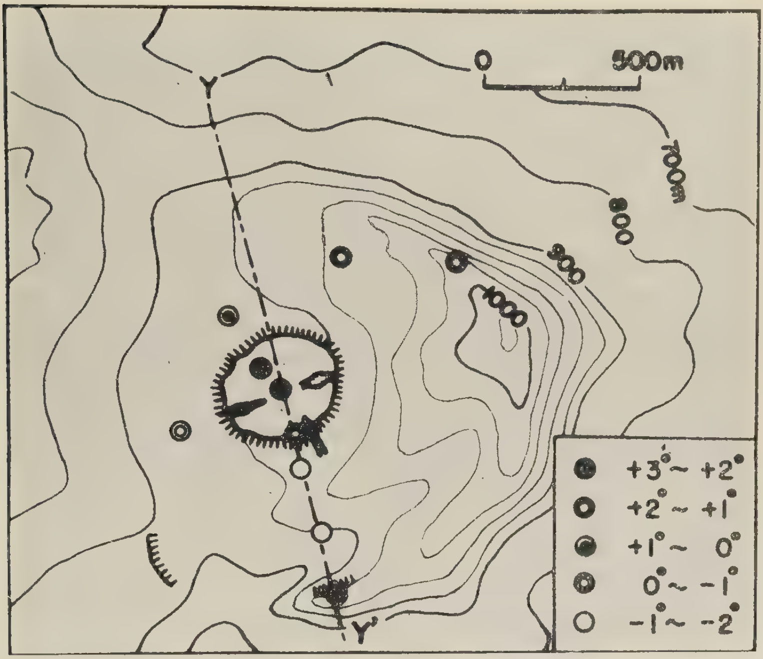

Fig. 10. (a) - Anomalous distribution of geomagnetic dip due to magnetization of the 1909 lava-dome on Mt. Tarumai.

three days in April, 1909. Its interior was found still incandescent several days after its extrusion. It is about 400 m in diameter and about 120 m in height above the surrounding atrio. The top is rather flat. Measurements of the geomagnetic dip were made at 12 spots in the area, 3 on the top of the dome, 5 around the dome, 2 on the somma and 2 at the foot of the volcano. The geomagnetic dip increases at the top and decreases at the foot of the dome. The anomaly may be explained satisfactorily by the magnetization of the dome in the direction of the present geomagnetic north with average intensity of 0.005 emu/cc. The mentioned intensity is in good agreement with the remanent magnetization of the lava measured in the laboratory by NAGATA's colleagues. In short, the new lava, which issued in the form of a massive dome, also disturbs the general geomagnetic field around it, and the anomaly is ascribed mostly to its thermoremanent magnetism.

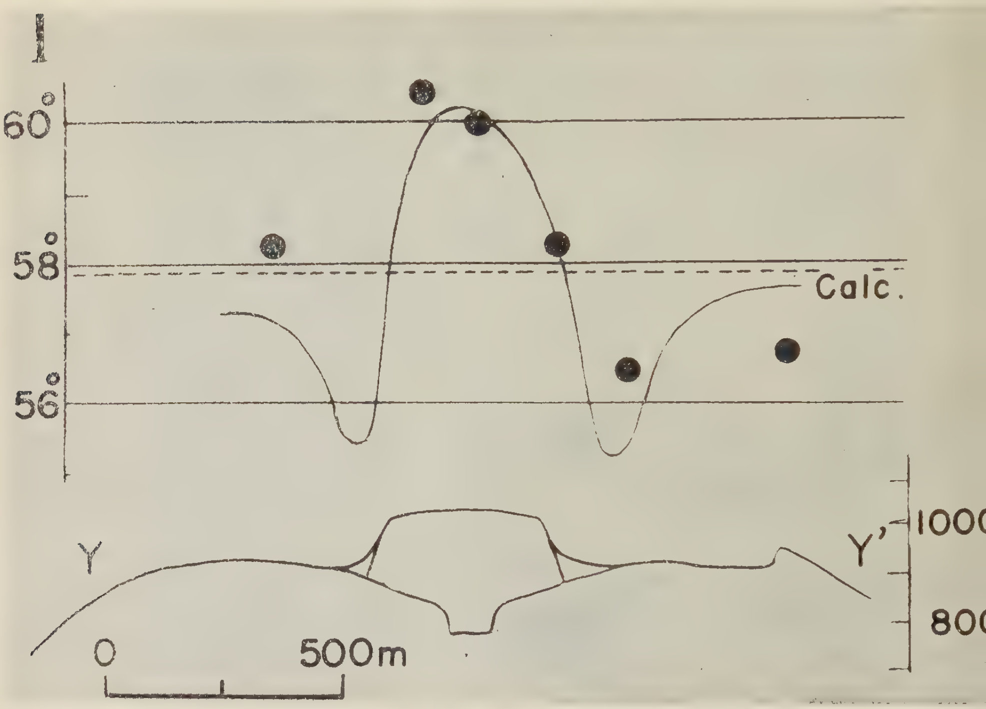

Fig. 10. (b) - Anomalous distribution of geomagnetic dip due to magnetization of the 1909 lava-dome on Mt. Tarumai.

From the three observations of actual large lava masses, we may safely conclude that the geomagnetic anomalies and changes near the new lavas are always much more affected by their thermoremanent magnetization which was acquired gradually as they cooled down, than by induced magnetism.

4) Change in the geomagnetic field accompanying volcanic activities

Remarkable changes in the geomagnetic field were observed at the time of volcanic activities of Miyake-sima in 1940 21) by one of the writers and others and Oo-sima during 1950-1954 by T. Rikitake 22). The geomagnetic dip decreases during the volcanic active periods. The declination changes also in accord with the changes in dip. Similar but less remarkable changes were also studied at Asama by one of the writers 23).

This phenomenon cannot be explained by the magnetic effect due to extruded lavas only, and should be regarded as of subterranean origin. It presumably results from a change in the remanent magnetization of the underground rocks due to rise or fall of their temperatures through the Curie-points 24). But we will not enter into the details of this problem here.

6. Anomalous Distribution of the Magnetic Field around and in the Crater

The geomagnetic declination around the craters of Volcanoes Asama and Mihara (Oo-sima) were measured by the aid of magnetic compass by T. Nagata 25) and T. Fukutomi 26), and it was found out that the observed geomagnetic anomaly is affected greatly by the particular topography around the crater, which is nearly symmetric with respect to the center of the crater.

T. Nagata compared the anomalies with calculated ones due to homogeneously magnetized model of the central cone having a crater, and concluded that these central cones are magnetized by remanent magnetism of volcanic materials and induced magnetism due to the present geomagnetic field. Y. Harada 27) measured the geomagnetic vertical component at 40 spots around the Toya Caldera Lake. He concluded that the geomagnetic field there is very much affected by the topographies of the caldera which is magnetized in the present geomagnetic field. Susceptibility of the southern part was about thrice of the more acid northern part of the caldera.

On the other hand, the writers found the anomalous distribution of the geomagnetic field from measurements of dip in and near the craters of central cone of Volcano Kusatu-Sirane 28). To get the mean magnetic intensity of the cone, calculation was done taking small topographies of the central cone into account. From the calculation we estimated the mean intensity of magnetization of volcanic materials composing the crater at 0.8×10^{-3} e.m.u., which coincides with what may be expected from susceptibility of andesite rocks. Accordingly, this fact suggests that the volcanic materials of the cone as a whole possess more induced magnetism than remanent one. The remanent magnetism may be cancelled in a volcano which is composed of pyroclastic materials.

7. Geomagnetic Anomaly and Characteristics of Volcanoes

In order to make the magnetization of volcanoes clearer, we investigated the results obtained in surveys of the magnetic dip conducted mainly by us at other volcanoes, that is, Sakura-sima, Miyake-sima and so forth.

One of the remarkable characteristics of the distribution of magnetic dip is the increase of dip with the increase of altitude.

From the view-point of potential of uniformly magnetized mountain-body, it is quite natural to express the phenomenon by the following formula:

$$\overline{\Delta I} = \frac{3}{4} \frac{J \sin 2I}{F\, k^2 \rho} \frac{\partial^2 V}{\partial Z^2}$$

where, $\Delta \bar{I}$; the mean value of anomaly at equal height of a circular simmetric model of volcano, F; the total intensity of the geomagnetic field, V; the gravity potential of the volcano, k^2; the gravitational constant, ρ; mean density of the volcano, I; the normal value of magnetic inclination at the volcano. It is needless to say that the phenomenon above described is seriously affected by fluctuations in topography.

On Fig. 11 is shown an example of the relationship between the anomaly of dip and altitude in the case of Mt. Huzi.

On the other hand, the rate of increase of magnetic dip from the foot to the summit depends mainly upon the intensity of magnetization of volcanoes, though these phenomena are more or less affected by their volumes and shapes. To compare the magnetic intensity of volcanoes, similar illustrations as made for Mt. Huzi (Fig. 11) were shown in Fig. 12. At a glance of this figure, it will become clear that the magnetic intensities of Volcanoes Huzi, Miyake, Oo-sima and Oomuro are markedly larger than those of Asama, Sakura-sima and Kusatu-Sirane and others. Seeing this phenomenon, we hit upon an interesting relation, namely, that the former four are rather basaltic volcanoes and the latter three are

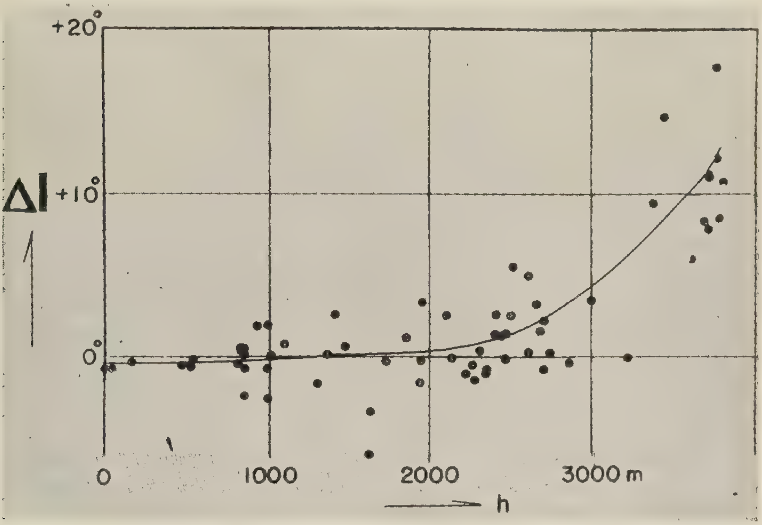

Fig. 11. - Relation between dip and height (a. s. l.) at Mt. Huzi.
h; height (a. s. l.) of the observation spot.
ΔI; anomaly of dip.

typically andesitic. The mean weight percentages of SiO_2 of rocks composing these volcanoes are as follows: 51.4 % for Mt. Huzi, 53.9 % for Miyake-sima, 62,1 % for Asama, 62.1 % for Sakura-sima and 61.9 % for Kusatu-Sirane respectively.

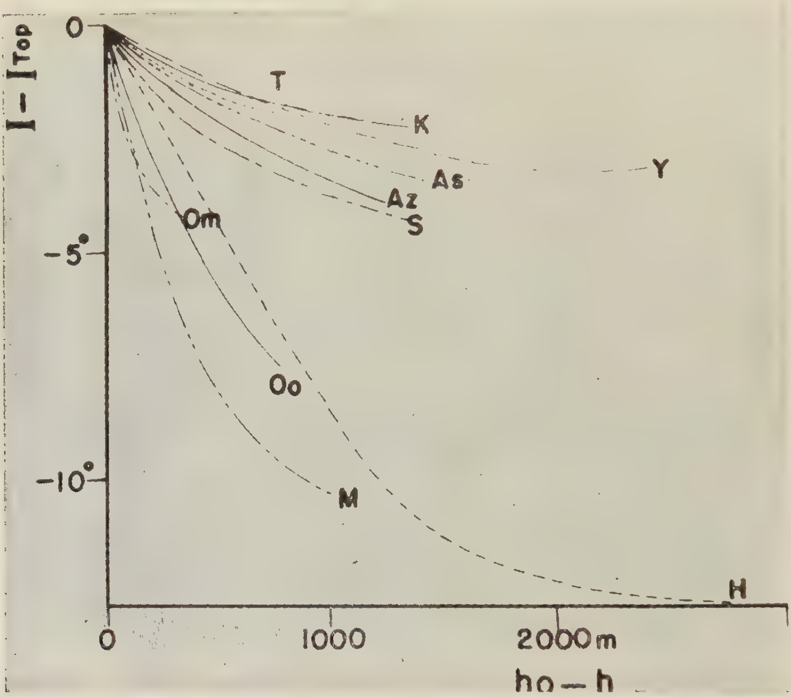

Fig. 12. - Relation between dip and height at various volcanoes.

I Top; dip at the summit of volcano.
I ; dip at the flank and foot of volcano.
ho ; height (a.s.l.) of the summit.
h ; height (a.s.l.) of the other observation spots.

H; Huzi M; Miyake-sima Oo; Oo-sima Om; Oomuro
Az; Azuma S; Sakura-sima As; Asama Y; Yakeyama
K; Kusatu-Sirane T; Tarumai.

The first cause conceivable is the petrographical fact that quantity of magnetic minerals such as magnetite increases as the percentage of silica decreases. The next one, from the volcanological stand-point, is the difference in the mode of accumulation of magnetized ejecta due to the difference in viscosity. Since andesite is highly viscous even at high temperature around 1000° C, the lava-flows of andesitic volcanoes are in most cases of block type which is less stable dynamically than fluid-like lava-flows which are seen generally in the case of basaltic volcanoes. As the result, after they cooled down in the geomagnetic field and acquired thermo-remanent magnetism, the direction of magnetization of basaltic lavas may be less disturbed by rolling and displacement of lava materials than andesitic ones. In addition to that, andesitic volcanoes are richer in small pyroclastic lava fragments as pumice and lapilli. It is reasonable to think that those small and loose ejecta possess random directions of remanent magnetism at present, or exist in the form of glassy materials.

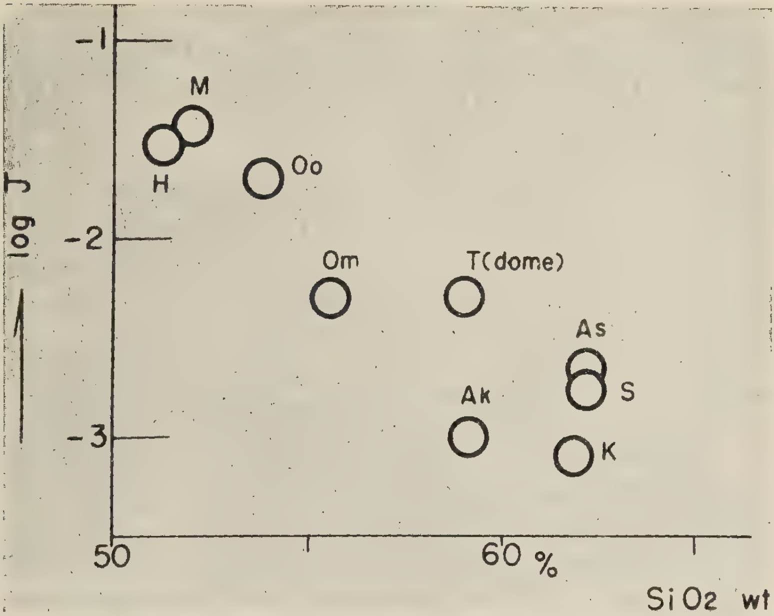

Fig. 13. - Intensity of magnetization of the volcanoes and mean silica content of the respective volcanoes.

H; Huzi M; Miyake-sima Oo; Oo-sima Om; Oomuro
T; Tarumai Ak; Akagi As; Asama S; Sakura-sima
K; Kusatu-Sirane.

Table 1. - Magnetization of volcanoes.

Volcano	Rock	SiO_2 (wt%)	J in emu/cc	Survey
Huzi	basalt	51.4	0.03 (Minakami)	Minakami
Oo-sima	basalt	51.8 (somma)	0.037 (Rikitake)	Rikitake
		52.0 (crater)		Nagata
Miyake-sima	basalt	53.9	0.02 (Minakami)	Minakami
» lava			0.012 (»)	»
Oomuro	andesite	53.8-57.4	0.005 (Rikitake)	Nagata
Tarumai (dome)	andesite	57.4-61.3	0.005 (Sakuma)	Sakuma
Asama	andesite	62.1	0.0022 (Minakami)	Minakami
Sakura-sima	andesite	62.1	0.0018 (»)	»
» lava			0.005 (»)	»
Akagi	andesite	56. -71.	0.001 (Rikitake)	Rikitake
Kusatu-Sirane	andesite	61.9	0.0008 (Minakami)	Minakami

Briefly, it may be concluded that the geomagnetic anomaly on and around a volcano has close correlation with the acidity of rocks and the structure of the volcano.

8. Conclusion

In this paper, the writers have described the outline of geomagnetic phenomena of volcanoes in Japan and given the interpretation from the volcanological stand-point.

On the basis of geomagnetic surveys of Mt. Huzi and other volcanoes 29), we have made clear that active and dormant volcanoes in Japan are magnetized nearly towards the north.

Although the intensity of magnetization of these volcanoes depends markedly on the chemical composition of lavas, namely, whether they are basaltic or andesitic, it depends also on the structures of these volcanoes. It is common to volcanoes that their magnetizations are caused partly by the remanent magnetization and partly by the induced magnetism. According to Nagata's experiments of lava-specimens collected from various volcanoes, the intensity of thermo-remanent magnetism of rocks is generally several or ten times that of induced one. But in the actual geomagnetic phenomena of volcanoes, it is found that anomalous distributions of geomagnetic force near the andesitic volcanoes such as Kusatu-

Sirane are seriously affected by induced magnetism due to the present geomagnetic field, and not by the remanent one. On the contrary, the intense magnetization of new lava-flows such as that of Miyake-sima in 1940 or Sakura-sima in 1946 is almost perfectly explained by the thermo-remanent magnetism, and not by the induced magnetism only.

From the geomagnetic phenomena mentioned above, it may be concluded reasonably that the geomagnetic anomaly of volcanoes should be explained not only on the foundation of magnetic properties of lava-specimens but also by taking the structures of volcanoes into account. We hope that numerous problems with respect to subterranean structures of volcanoes and their history will be brought to light in the near future, on the basis of future observations of geomagnetic phenomena and experiments on magnetism of rocks.

In conclusion, the writers wish to express their sincere thanks to Mr. K. Matsushita, Mr. K. Iwama, Mr. S. Uchibori and Miss T. Takahashi for their cooperation in their field investigations and in preparation of this paper.

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Fig. 11. Mt. Huzi (Fuji) seen from the north.

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Radioactivity of Volcanic Gases in Japan

1) - Introduction

If a great part of the volcanic heat at the volcanic activities is derived from the radioactive elements in the earth's crust, it is very important to know the radioactivity of the volcanic gases. But they were seldom measured. N. N. Shavrov [1] measured the radon (radium emanation, Rn) contents of the fumarole gases of Volcano Tuĭla and Kirchurich in Kamchatka ($0.056\text{-}0.117 \times 10^{-10}$ curie/l) and O. Scarpa [2] measured the radioactivity of the fumarolic gases in Ischia Island, Italy.

Since 1942, in order to study the relation between the radioactivity of the volcanic gases and the volcanic activities, we have studied the radioactivity of the volcanic gases from the fumaroles and the hot springs, and found that the gases from Hokozigoku Hot Spring in Aso Volcanic District in Kumamoto Prefecture, Kyusyu, have abnormally higher radon contents than that has been expected from the radon contents of the hot water itself [3, 4]. In 1948, K. Kuroda and Y. Yokoyama have confirmed the existence of RaA and RaC in the fumarolic gases [5]. In 1949, one of the present authors (Iwasaki) and his co-workers [6] discovered the existence of thoron (thorium emanation, Tn), isotope of radon, and thorium A, isotope of RaA, in the fumarolic gases in Beppu Hot Spring District and Kuzyu Volcanic Region (both in Ooita Prefecture, Kyusyu) and that the contents of these radioactive constituents in the volcanic gases are larger in the small fumaroles than the larger powerful fumaroles as a whole, and that the radioactivity of thoron in the volcanic gases is generally larger than that of radon in the same volcanic gas. Therefore, one of the present authors (Kamada [7]) measured the radioactivity of many volcanic gases in Kyusyu District, and confirmed the existence of many radioactive elements such as Rn, RaA, RaB, RaC, Tn, (ThA) and ThB in these volcanic gases. In recent years the radioactivity of the volcanic gases from the craters, the fumaroles and the hot springs was measured by many investigators in Japan and some interesting results were obtained. The radioactivity of the volcanic gases of Vulcano Island in Italy was also reported by L. Sicardi [8]. With the object of studying the nature of the radioactivity of the volcanic gases in more detail, the present authors have measured the radioactivity of a great number of volcanic gases from the fumaroles and the hot springs. In the present paper we shall give the summary of the results obtained.

2) - Radioactivity of the Volcanic gases in Japan

Measurements of the radon and thoron contents [9] of the volcanic gases were carried out with an I. M. Fontactoscope (made in the Scientific Research Institute, Tokyo, Japan) [10]. The radioactivity of some volcanic gases in Japan is shown in Table 1.

As will be seen in Table 1, the existence of a considerable amount of Rn and Tn (ThA) in nearly all of volcanic gases in Japan was ascertained by these investigations. It is also confirmed that the radioactivity of thoron in the volcanic gases is generally larger than that of radon in the same volcanic gases. These results obtained are in good harmony with the former studies [3, 4, 6, 7]. The radioactivity of the volcanic gases in Japan is never negligible small as that of the volcanic gases in Kamchatka [1], but often so large as comparable to that of the gases from the strongly radioactive mineral springs and to that of the volcanic gases from Vulcano Island, Italy [8] (Table 4). Furthermore, the Tn contents amounting to 5.600 mache [7] - (Tn + ThA) 11,300 mache [7] of the Siratori Fumarole gas in Kirisima Volcanic Region in South Kyusyu are the highest value in the world for the radioactivity of natural gases. The Rn contents amounting to 762 mache of Kamiyugo Fumarole gas are also remarkable com-

Table 1.

Radon and Thoron Contents in Japanese Volcanic Gases.

Name of Sample	Locality	Date	Temp. (°C)	Rn (mache)	Tn (mache)	Tn/Rn
Konyazigoku	Noboribetu Hokkaido	July 28, 1952	100	1.5	—	—
geyser	»	»		16	—	—
»	»	»		26	—	—
Taihozigoku	»	»	37	32	65	2
Syowasinzan	Hokkaido	29,		2.6	—	—
Hutamata No. 3	»	30,	22	4.9	—	—
» No. 4	»	31,	45.5	0.78	—	—
» No. 6	»	»	33.0	1.7	—	—
» No. 7	»	»	32.0	1.9	14	7.4
Osoresan No. 1	Aomori Pref.	Aug. 2,	39.0	7.4	?	—
» No. 2	»	»	59.0	7.2	—	—
» No. 3	»	»	86.5	7.7	—	—
» No. 4	»	»	70.0	17	—	—
», Syurao (geyser)	»	3,	71.5	11	—	—
», »	»	»	72.0	3.5	—	—
», »	»	»		4.5	—	—
», »	»	»		7.1	—	—
Tamagawa Hot Spring						
Oohuki No. 0	Akita Pref.	Oct. 17, 1952	89	3.4	30	8.8
» No. 1	»	»	97	2.9	—	—
» No. 1 a	»	»	97	2.9	—	—
» No. 1 b	»	Oct. 17, 1953	98	2.0	—	—
» No. 2	»	»	93	2.6	230	88.4
» »	»	18,	95	1.7	120	70.6
» No. 3	»	Oct. 18, 1952	93	9.0	2300	255.5
» No. 4	»	»	94	15	1200	80
» No. 5	»	»	98	6.3	600	95.2
» No. 6	»	»	96	0.4	150	375
» No. 7	»	»	97	2	20	10
» No. 8	»	»	97.5	3∾9	540	90
» No. 10	»	19,	73	3.9	—	—
» No. 11	»	»	71.6	2.2	—	—
Dokugasuzawa No. 1	»	18,	90	20	230	11.5
» No. 1	»	Oct. 9, 1953	96	48	140	2.9
» No. 2	»	Oct. 18, 1952	91	22	170	7.7

Table 1 (continued)

Name of Sample	Locality	Date	Temp. (°C)	Rn (mache)	Tn (mache)	Tn
Dokugasuzawa No. 3	Akita Pref.	Oct. 18, 1952	93	11	330	
» No. 4	»	»	47	24	—	
Higasimori No. 2	»	Oct. 10, 1953		4	—	
» No. 3	»	»		3	—	
Sassyozawa No. 1	»	»	94	12	100	
» No. 2	»	»	95	—	—	
Kagamizawa No. 1	»	Oct. 17, 1952	51.6	12	26	
» No. 2	»	»	80	9	31	
» No. 3	»	»	45	21	—	
» No. 4	»	»	85	9	—	
» No. 5	»	»	89	10	—	
» No. 6	»	»	82	27	—	
» No. 7	»	»	95	6.6	—	
» No. 8	»	»	96	10	110	
Hatimandaira Volcano						
Yakeyama No. 1	»	Oct. 19, 1952	95	5.6	—	
» No. 2	»	»	97	18	—	
» No. 2	»	Oct. 12, 1953	93	11	—	
» No. 3	»	Oct. 19, 1952	95	7	37	
» No. 4	»	»	88	14	—	
» No. 6	»	Oct. 12, 1953	93	11	—	
» No. 7	»	»	69	11	10	
Sakebizawa No. 1	»	Oct. 20, 1952	79	16	210	
» No. 2	»	»	95	13	—	
» No. 3	»	»	98	16	—	
Miyakawa mine	»	Oct. 12, 1953	90	6	—	
Gosyogake No. 1	»	Oct. 13, 1953	95	75	470	
» No. 3	»	»	86	100	—	
» No. 4	»	»	88	100	tr	
Hukenoyu No. 1	»	15,	95	90	470	
» No. 2	»	»	95	120	600	
» No. 3	»	»	95	90	600	
4 No. 4	»	»	87	630	1800	
Issaikyo Volcano						
Takayu No. 1	Hukusima Pref.	Oct. 16, 1953	40.5	none	—	
» No. 2	»	»	43.5	0.3	—	
» No. 3	»	»	49	0.6	—	
», Tamagoyu	»	»	43.2	1.4	—	
Issaikyo No. 1	»	17,	>120	—	—	

Table 1 (continued)

Name of Sample	Locality	Date	Temp. (°C)	Rn (mache)	Tn (mache)	Tn/Rn
saikyo No. 2	Hukusima Pref.	Oct. 17, 1953	>120	0.5	tr	—
» No. 3	»	»	95	2	—	—
» No. 4	»	»	95	9	—	—
» No. 5	»	»	95.3	3	—	—
» No. 6	»	»		6	—	—
» No. 7	»	»	91.8	2	—	—
» No. 8	»	»	91.2	2	—	—
andai Volcano						
asikura No. 2	»	18,	94.8	22	none	—
» No. 3	»	»	86.7	65	—	—
» No. 4	»	»	91	80	—	—
» No. 5	»	»		40	—	—
» No. 6	»	»		16	—	—
» No. 7	»	»		30	—	—
ozi No. 1	»	19,	93,3	75	—	—
» No. 2	»	»		110	—	—
unkayu No. 1	»	»		20	—	—
» No. 2	»	»		20	—	—
» No. 3	»	»		9	—	—
akone Volcano						
owakidani No. 1	Kanagawa Pref.	Dec. 28, 1951	86	12	—	—
» »	»	29,		11	20	1.8
» »	»	Apr. 8, 1952	87	8	13	1.6
» »	»	Dec. 29, 1953	86	6	19	3.2
» No. 2	»	30,		10	—	—
so Volcano						
otituki	Kumamoto Pref.	Nov. 21, 1946	93.0	43	—	—
»	»	»	»	33	—	—
oko-zigoku	»	Aug. 27, 1944	81	68	—	—
»	»	Oct. 24, 1948	81	208	—	—
iroike	»	Aug. 19, 1943	66	31.5	—	—
eppu Hot Springs						
ozu-zigoku D_2	Ooita Pref.	Dec. 28, 1948	93	68	—	—
niosibozu	»	»	97	36	—	—
ozu-zigoku A	»	Mar. 20, 1949	99	35	—	—
» C	»	»	93	98	—	—
» D_2	»	»	83	63	450	7.1
» T_1	»	»	27	117	240	2

Table 1 (continued)

Name of Sample	Locality	Date	Temp. (°C)	Rn (mache)	Tn (mache)	Tn/
Bozu-zigoku E$_1$	Ooita Pref.	Mar. 20, 1949	84	54	390	
» E$_2$	»	»	83	64	380—620	6-1
» »	»	»	98	36	330—420	9-1
» T$_2$	»	May 7, 1949	93	102	310—380	3
» T$_3$	»	»	98	92	340	
Turumien	»	Mar. 19, 1949	86	0.3	—	—
»	»	»	82	1.1	—	—
»	»	»	98	0.6	—	—
Itaike-Hatiman	»	22,	97	8.6	—	—
»	»	May 8, 1949	99	5.7	—	—
Kuzyu Volcano						
Komatu-zigoku	»	May 5, 1949	94	128	100	
»	»	»	31	210	340—500	1
»	»	»	94	66	200	
Yamanoie No. 1	»	»	15	0	0	—
» No. 2	»	»	»	0	0	—
» No. 3	»	»	»	0	0	—
Kirisima Volcano						
Maruo	Kagosima Pref.	Aug. 6, 1950	90	71	—	—
Kurinodake No. 1	»	Aug. 28, 1951	88	33	1170	3
» No. 2	»	»	97.7	20	470	2
» »	»	Jan. 14, 1951	97.8	17	—	—
» »	»	Aug. 28, 1951	85	33	310	
» No. 4	»	Sep. 1, 1950	90.5	36	—	—
» No. 5	»	Aug. 28, 1951	66.5	79	390	
» No. 6	»	Aug. 31, 1950	90.7	31	—	—
» No. 7	»	Aug. 27, 1951	69	75	940	
» »	»	Jan. 14, 1951	72	60	—	—
» No. 8	»	Aug. 31, 1950	94	54	—	—
» No. 9	»	Aug. 27, 1951	86.1	107	180	
» »	»	Jan. 15, 1951	85.0	74	—	—
» »	»	Sep. 1, 1950	92.9	76	—	—
Siratori No. 1	»		94	202	5700	2
Tearai-Ro	»		69.5	717	4000	
Ora No. 1	»		40.2	157	2100	

Table 1 (continued)

Name of Sample	Locality	Date	Temp. (°C)	Rn (mache)	Tn (mache)	Tn/Rn
amanozyo	Kagosima Pref.		42.5	142	1700	11.9
utinoerabu	»		98.2	10.6	—	—
uooyama	»		97	2.8	—	—
usuki Volcano						
ongenyama	»	June 3, 1951	90.7	570	—	—
amiyogo No. 1	»	9,	99	270	—	—
» No. 2	»	3,	99	760	—	—
imoyugo	»	9,	98.2	730	—	—
umarole	»	10,	97	20.8	—	—
amitamari	»	2,	98.6	230	—	—
nagi J	»	30,	99.6	140	—	—
» E	»	»	95.5	145	—	—
» H	»	July 2, 1951	62	210	—	—
» I	»	3,	27.1	340	2500	7.4
uzime	»	May 16, 1951	97	17	—	—
akurasima Volcano						
inamidake	»	May 5, 1951	93	3.6	—	—
»	»	»	»	3.1	—	—
urokami	»	July 15, 1950	95	0.07	—	—
ikine No. 1	»	June 24, 1951	19.5	0.9	—	—
» No. 9	»	»	»	0.45	—	—
» No. 17	»	»	20.0	1.55	—	—

pared with those of the well-known strongly radioactive mineral spring gases of Masutomi and Ikeda Mineral Springs in Japan as shown in Table 2.

Among them, we can recognize the fact that there are many volcanic gases of larger contents of these radioactive elements in Kyusyu Volcanic Region than in the other part of Japan as a whole. It is this point that we have endeavoured to make clear, but we cannot yet understand the reasons.

On the other hand, the volcanic gases from the active craters and from the neighbourhoods of active craters are not so radioactive as will be seen in Table 1. For example, the Rn contents of volcanic gases of the fumaroles on the lava lake

Table 2.

Radon and thoron contents of the gases of strongly radioactive springs.

Name of Spring	Tem. (°C)	Tn (mache)	Rn (mache)	Name of Researcher
Masutomi Mineral Spring	—	—	1514	I. ISHIZU (1915). [11].
Ikeda Mineral Spring	—	—	378	I. IWASAKI (1943). [12].
Misasa Mineral Spring	68.5	—	330	I. ASHIZAWA (1949). [13].
Masutomi Mineral Spring-B7	26.3	167	19.5	K. KURODA and Y. YOKOYAMA. [14].

of Volcano Oo-sima, Izu are small as 1-3 mache [15], but since the quantity of emission of the volcanic gases was also very large, considerably large quantity of radioactive substances was emitted during the volcanic activities. Considering that the radium contents of the volcanic rocks of Volcano Oo-sima are $0.09\text{-}0.18 \times 10^{-12}$ g/g [16], we can imagine that the radon in the volcanic gases was liberated from a large quantity of rocks at high temperature by volcanic activities as the fusion method [17] for the determination of radon in rocks and collected in the volcanic gases. It is also notable that the radon contents of the volcanic gases from various volcanic regions are not so different from each other as follows: Miharayama (Volcano Oo-sima, Izu), 1-3 mache [15]; Syowasinzan (Volcano Usu), 2.6 mache [18] and also see in Table 1; Aso-Nakadake (Volcano Aso), 4.92 mache [19]; Sakurazima-Minamidake (Volcano Sakurazima), 3.57 mache [7].

As will be seen in Table 1, the range of the radon contents of the volcanic gases is considerably wide and the radon contents of each fumarole in one fumarole group are often very different from each other, even when there is only a few meters distance between the two fumaroles, while the contents of the principal chemical constituents, CO_2 in the cases studied, are generally very similar to each other. This nature is the same in the case of the strongly radioactive mineral springs [12, 13, 20, 21], and of the other nature of the fumaroles as a whole [22]. Although there is no remarkable regularity between the radon contents of the volcanic gases as a whole described above, it seems that generally the quantity of radioactive substances effusing from one fumarole in one volcanic region has a definite limit according to the properties of rocks and the geological environments [6] as already known in the strongly radioactive mineral spring (Table 3)

Table 3.

Relation between radon contents and amount of flow.

Name of Spring	Rn	Amount of flow (1/min.)	Total amt. of Rn ($\times 10^{-12}$ curie/min.)
Oberschlema Mineral Spring *			
Hindenburg	13500	1	49000
Bismarck	3000	1	11000
Radiumgesenk	330	35	42000
Jung-König-David-Flügel	25	ca. 500	46000
Ikeda Mineral Spring			
No. 8	4330	0.22	3700
No. 4	1550	0.84	4700
No. 3	229	2.1	1800

* C. Genser: Geol. Rundschau, 23, 188 (1932); Ber. deut. geol. Gesellschaft, 85, 482 (1933).

[21]. Under these circumstances stated above, it is easy to understand the fact that the radon contents of the fumaroles, that are more active and powerful and have a larger quantity of gas emission, are distinctly smaller than those of the very small and weak fumaroles in the same fumarole group such as in Beppu and Kuzyu Volcanic Region [6] and South Kyusyu Volcanic Region [7] in Japan shown in Table 1, and in Vul-

cano Island, Italy shown in Table 4. [8]. The similar tendency is well known in the case of the strongly radioactive mineral springs [20, 21], and it offers a base to the sinter theory of the formation of strongly radioactive mineral springs, that the origin of radon in the mineral springs is quite near to the ground surface and it may be the radioactive sinters which have the especially large radium contents. [21, 23, 24, 25].

Table 4.

Radon contents of volcanic gases in Vulcano Island, Italy [8]. (measured by L. Sicardi in 1923).

Fumarole	T^0, C	Radon contents (mache)	Gas (dry) (l.)	H_2O (kg)
Cratere	480	22.4	50	1.100
	237	21.6		
Faragl. Levante	100	15.9	7	1.281
	100	16.1		
	98	15.0		
Lentia	100	166.6	5	0.805
	100	158.3		
	99	159.6		

3) - The properties of the radioactivity of volcanic gases and their origin

a) - Variation of the radioactivity of volcanic gases

Variations of the radon contents of the volcanic gases from some fumaroles are recognized certainly as will be seen in Table 1, but the radon contents of the volcanic gases from the most part of the powerful fumaroles are considerably constant in every season and also under different conditions of one season as will be seen in Table 5. [7].

Table 5.

Observation of Rn contents and Tn/Rn ratio of one fumarole gas Sample [7].

Kurinodake-Maenoyu-2.

Exp. No.	Date of sampling	Atmos. Press. mm. Hg.	Temp. (°C)	Tn/Rn	Rn (mache)
—	Sep. 2, 1950	692	66.9	—	59
—	Jan. 14, 1951	705	72.0	—	60
—	Jan. 15, 1951	702	68.0	—	52
310	Aug. 27, 1951	700	67.7	11	76
316	Aug. 27, 1951	702	69.0	13	73
324	Aug. 28, 1951	698	68.0	11	79
346	Aug. 31, 1951	699	60.0	12	68
379	Jan. 1, 1952	691	70.7	9	66
403	Mar. 13, 1952	698	61.0	12	77
421	Apr. 17, 1952	703	65.9	10	75
441	Apr. 18, 1952	695	63.2	12	68
482	July 11, 1952	699	62.0	9	66
				(CO_2 %)	
327	Aug. 29, 1951	695	68.5	(86)	73
329	»	696	70.8	(85)	73
331	»	695	64.0	(86)	69
333	»	695	64.5	(87)	73
336	»	693	54.2	(85)	69
338	»	694	60.5	(85)	73

This fact exhibits the striking contrast to the fact found about the strongly radioactive mineral springs such as Masutomi and Ikeda Mineral Springs in Japan, which have been said to change remarkably their radon contents by various external conditions such as rain and snow fall, freezing of the ground surface, rise and fall of atmospheric temperature and pressure, etc. [21, 23, 24]. The variations of the radon contents of hot springs were attained chiefly from the study of spring water itself, and the same variations have also been suspected in the case of spring gases. This characteristic property of the strongly radioactive mineral springs has been considered as a fact for the starting point to the sinter theory for the formation of the strongly radioactive springs described above [21, 23, 24], that the origin of the radioactive substances in such springs is quite close to the ground surface. From the same stand-point, the origin of the radioactive substances in the volcanic gases must be rather far below the earth surface and their contents are generally unaffected by meteorological conditions. This view is in good harmony with the fact that the temperature of the most powerful fumaroles is remarkably constant under various meteorological conditions, and when the nature of these powerful fumaroles is altered, the remarkable changes are always recognized in the geological environments of these fumaroles.

As already mentioned above, the radon contents of the most part of the powerful fumaroles are almost constant, but

Table 6.

Periodic Variation of the Radon Contents of the Volcanic Gases of Hokozigoku Geyser [3, 4, 20].

Date		Radon (mache)
Aug. 9, 1942	quiet	62.5
»	eruption	43.9
10,	eruption	43.7
11,	quiet	61.6
Aug. 27, 1944	25 min. before eruption	68.1
28,	20 min. »	52.6
29,	12 min. »	45.1
27,	just before »	41.7
29,	3 min. after eruption	35.2
»	»	32.3
28,	5 min. »	31.1
29,	11 min. »	30.8
28,	14 min. »	32.5
26,	more than two hours after eruption	27.5
»	more than 6 hours after eruption	21.5
Oct. 22, 1948	eruption	61.2
24,	quiet	208

there is an exception in the special case such as geysers in the volcanic regions. The periodic variation in chemical composition of hot spring waters and hot spring gases from Hokozigoku Geyser was already known [3, 4] and the periodic variation of radon contents of the volcanic gases of the geyser is shown in Table 6 [3, 4], and the same variation was also recognized in the volcanic gases from the geysers in Noboribetu Hot Spring, Hokkaido and Osoreyama Volcanic Region in Aomori Prefecture as will be seen in Table 1.

But in these cases, it seems also to have a definite limit of the quantity of the radioactive substances as described above, consequently the radon contents of these volcanic gases are larger in the gases of the quiet period than in that of the eruption period in which gases are effused much more than in the quiet period. These properties of the volcanic gases from the geyser are very important for the explanation of the geyser [26].

b) - Ratio (Tn/Rn) in the volcanic gases

The most interesting and important fact for the origin of the radioactive substances in the volcanic gases and the mechanism of the introduction of these radioactive substances into these volcanic gases is the radioactivity ratio of thoron to radon (Tn/Rn) of one volcanic gas. If the origin of these radioactive components is the same, and is situated in the same position, the ratio (Tn/Rn) will become smaller as the time spent by the transportation of these radioactive substances by volcanic gases from their origin to the earth surface where they are sampled is longer, because the half-life of thoron (54.5 sec.) is very short compared with that of radon (3.825 days). As this ratio (Tn/Rn) may be invariable even if the main chemical components of the volcanic gases change, or the secondary components except these radioactive components are introduced independently each other into the primary components at the fumarole-path from their origin to the earth surface, because they are isotope each other, consequently, the variation of the ratio (Tn/Rn) may be regarded to suggest the change of the time required from its origin, owing to the change of effusion intensity of volcanic gases and can be employed to detect the variation of the volcanic activities.

In Table 1, the ratio (Tn/Rn) of some volcanic gases is shown, but typical examples among the data are shown in Table 5. As will be seen in Table 1 and Table 5, the ratio (Tn/Rn) of the volcanic gases in Japan has a considerably wide range, but this ratio of one volcanic gas is nearly constant unexpectedly in spite of the general tendency of varying intensity of the effusion of the fumarole due to the various factors such as change in volcanic activity, change in atmospheric pressure etc. From the ratio (Tn/Rn) shown in Table 5, the origin of radon and thoron must be considered as rather near to the earth surface, contrarily to the result obtained from the variation of the contents of radioactive components described above. Based on simple calculation, it was concluded that the time of transportation of the radioactive components from their origin would not exceed 10 minutes in such cases [7].

c) - The partition of radon between volcanic gases and waters in the fumaroles

The fumaroles of weak and lower temperature are generally accompanied by hot water, and they should be regarded as hot spring waters from another stand-point. Consequently, the problem can be treated similarly as the case of the ordinary hot spring waters accompanying hot spring gases. As already mentioned above, the gas from Hokozigoku Hot Spring in Aso Volcanic Region has about 8 times as high radon contents as that has been expected from the radon contents of the water itself [3].

In the ordinary hot springs or mineral springs, radon is distributed between the gas phase and liquid phase according, principally, to the partition coefficient of radon at its temperature and pressure. Otherwise, radon will be distributed to the liquid phase more abundantly. This tendency is generally well-known [3, 12, 21] as will be seen in Table 7.

Table 7.

Partition of Rn between water and gas in Misasa Hot Spring (T. Ashizawa).

	Date	Temp. (^{0}C)	Rn (water)	Parti. Coeff. (α)	Rn contents in gas (calc.)	(obs.)	excess %
Matubaranoyu	Sep. 4, 1949	68.5	140	0.12	1160	330	29
»	7,	68.5	62	0.12	560	310	60
»	Oct. 13, 1949	68.5	25	0.12	209	187	90
unotani	Sep. 11, 1949	35.0	24	0.17	139	91	66
abuyu	Sep. 8, 1949	41.5	11	0.15	70	62	89
»	———	45	10.2	0.145	70	62.3	89

Partition of Rn between water and gas in Ikeda Mineral Spring No. 1

	Date	Temp. (^{0}C)	Rn (water)	Parti. Coeff. (α)	Rn contents in gas (calc.)	(obs.)	excess %
Ikeda No. 1	Apr. 24, 1943	15.0	197	0.295	668	378	57
»	July 29, 1943	19.0	127	0.261	487	235	48

Partition of Rn between water and gas in Masutomi Mineral Spring.

	Date	Temp. (^{0}C)	Rn (water)	Parti. Coeff. (α)	Rn contents in gas (calc.)	(obs.)	excess %
	Dec. 1913	16.0	590.44	0.286	2064	1514.23	73

According to Kamada [7], the excessive distribution of radon in the gas phase of fumaroles is rather a common phenomenon in the most fumaroles accompanied by hot waters. Further, this is also verified for thoron [7]. Some of the results obtained are shown in Table 8.

Thus it is recognized that the radon contained in the fumarolic gases or in the hot spring gases closely related to the fumaroles has its origin not in the hot water or in the ground water near the earth surface, but in the volcanic gases themselves. Under these circumstances stated above, the radioactivity of the hot spring gases in the springs of high temperature can never be neglected; because in these cases radon is distributed chiefly in the gas phase, and sometimes, there is essentially an excessive distribution of radon in the gas phase. With regard to the mechanism of the formation of the radioactive hot springs, the hot spring water itself, and also the hot spring gases and the hot spring sinters should

Table 8.

Partition of Rn between water and gas in hot springs (South Kyusyu).

No.	Temp.	Partition Coeff. (α)	Rn in water	Rn in gas (A)	Rn in gas* (B) (calc.)	A/B × 100
1.	74.5	0.113	0.94	58.2	8.31	700
2.	60.7	0.126	0.77	50.9	6.11	833
3.	72.0	0.115	0.74	28.5	6.44	442
4.	84	0.110	0.33	6.8	3.03	224
5.	40.2	0.152	4.14	117	27.2	430
6.	66.9	0.120	0.87	4.11	7.25	57
7.	83.3	0.111	1.21	18.4	10.9	169
8.	82.0	0.111	2.02	31.0	18.2	170
9.	96.1	0.108	0.21	2.3	1.95	118
10.	80.0	0.112	1.94	22.8	17.3	132
11.	68.5	0.118	0.51	8.49	4.32	197
12.	73.8	0.113	0.20	0.44	1.77	25
13.	60.0	0.126	0.51	2.2	4.05	54
14.	39.8	0.152	0.18	1.11	1.18	94
15.	52.9	0.134	0.18	0.90	1.34	67
16.	53.0	0.134	0.15	1.25	1.12	112
17.	53.8	0.133	0.29	1.21	2.18	56
18.	46.5	0.141	0.76	3.19	5.39	59
19.	53.4	0.140	0.81	9.50	5.78	164
20.	59.3	0.127	0.33	3.52	2.60	135
21.	58.5	0.131	1.69	10.5	12.9	81
22.	53.0	0.133	0.75	7.26	5.64	129
23.	68.2	0.119	0.64	4.30	5.38	80
24.	56.5	0.131	1.30	4.28	9.92	43
25.	48.0	0.140	1.68	6.88	12.0	57
26.	49.2	0.139	3.31	16.8	23.8	71
27.	61.2	0.125	0.67	3.76	4.96	76
28.	59.3	0.127	0.51	116	4.02	2900

* Rn in water/partition coefficient = B.

be taken into consideration. From this stand-point the measurements of the excessive distribution of radon in the gas phase of many fumaroles in South Kyusyu were carried out by Kamada, and the excessive distribution of radon in the gas phase was found only in the central part where the volcanic activity was more active. This is in agreement with the theory that the volcanic or active volcanic hot springs are formed rather near the earth surface by both the fumarolic gases and the ground waters, together. The excessive distribution of radon in the gas phase could not be detected in any hot springs distributed in the distant part from the volcanic center. This may be regarded as one case which conforms to the DEVILLE's law.

These facts mentioned above should be considered as the peculiar property of the radioactivity of the fumarolic gases compared with the radioactivity of mineral springs in a common sense, consequently the origin of radon and thoron in the fumarolic gases seems to be different from that of the ordinary strongly radioactive mineral or hot springs.

d) - Relation between radioactivity of volcanic gases and that of strongly radioactive springs

As the mechanism of the formation of strongly radioactive springs seems to be explained successfully by the sinter theory [21, 23, 24] mentioned above, and it closely resembles that of the volcanic gases in many points, it is very interesting to attempt a comparative study on these two phenomena for the understanding of the origin of the radioactive substances in volcanic gases. If the radioactivity of volcanic gases will be taken as a special case of the radioactivity of the mineral spring gases that have a particularly strong radioactivity caused by their geological and balneological conditions, the problems will become rather simple. It is this point that we have endeavoured to make clear and we have reached at the conclusion that there are conspicuous differences between them and these differences suggest the important keys to solve the mechanism of the formation of them.

The geological environments of the fumarolic gases are all the same; namely, they are all issued from the volcanic rocks. These circumstances are also different from those of the well-known radioactive springs located mainly in the acid plutonic rocks, particularly in the pegmatitic or aplitic parts.

It is true that the large radium contents of acid plutonic rocks are the factor that caused the large radon contents of radioactive springs, but the abnormal high radon concentration and enrichment is regarded as a phenomenon of secondary quality, that is to say, the radon in the springs originated from the spring sinters especially enriched by radium. The mechanism of concentration of radium [25, 27] into the sediments from very dilute solutions such as sea water, lake water, and the collection of radon [25] into the natural waters and gases from these sinters are already explained successfully by one of the present authors [21]. This is the well-known sinter origin theory of radon in the mineral springs. Radioactive sinter itself can be found in many mineral spring districts in Japan, but the radioactive sinters have never been found in the neighbourhood of active volcanic districts where the radioactive fumarolic gases exist. Furthermore, many rock samples collected from Kirisima Volcanic Region where many strongly radioactive fumarolic gases exist showed only the ordinary radium contents which were comparable with those of the mother rocks (andesite) in each place. There is also no remarkable regularity between the radioactivity of fumarolic gases in various kinds of mother rocks. And the various attempts to discover the uncommonly strong radioactive sinters near the fumaroles and the hot springs situated close to the fumaroles, have all failed hitherto. As already mentioned, the large quantity of radon can be liberated and collected from the large quantity of the mother rocks by heating at high temperature as the fusion method for the determination of radon in rocks, consequently, the mechanism of the introduction of radioactive substances into the fumarolic gases might be considered to be different from that of the formation of strongly radioactive springs. In some cases, for example, such as in Tamagawa Hot Spring district as will be seen in Table 1, we can see the distinct difference of the distribution of the radioactive substances between the fumarolic gases and the spring gases, that the ratio (Tn/Rn) was much smaller in the fumarolic gases than that of the spring gases in the same hot spring district where the very large ratio (Tn/Rn) up to 500 was found. For the explanation of such a large ratio (Tn/Rn), we cannot help considering that their origin is quite near to the ground surface as usual strongly radioactive mineral springs. But we cannot yet explain completely the mechanism of the introduction of the radioactive substances into the fumarolic gases.

4) - Conclusion

We have measured the radioactivity of a large number of volcanic gases from the craters, the fumaroles and the hot springs in Japan, and found that the radioactivity of the volcanic gases in Japan is never negligibly small, but often so large as comparable to that of the gases from the strongly radioactive mineral springs, and ascertained the existence of many radioactive elements such as Rn, RaA, RaB, RaC, Tn, ThA, ThB, but actinon An (half-life, 3.92 sec.), isotope of Rn and Tn, is not yet found in the volcanic gases in Japan. The variation of the ratio (Tn/Rn) in the volcanic gases seems to suggest the variations of the volcanic activities. The radon contents of the most powerful fumaroles are almost constant all the year round, except the volcanic gases from the geysers in the active volcanic districts. The excessive distribution of radon and thoron in the gas phase of fumaroles is a common phenomenon in the most fumaroles accompanied by hot waters. In many cases, these radioactive fumarolic gases are considered as the principal sources of the radioactive substances in the hot spring waters situated closely to the fumaroles. The partition of radon and thoron in two phases may be a difficult problem of no less importance. Considering this fact, it cannot be said carelessly that the active volcanic hot springs have smaller radioactivity than the mineral springs. Geochemical investigations of the mechanism of the introduction of the radioactive substances into the volcanic gases of the fumaroles were carried out, but we cannot yet explain completely them. If volcanic eruptions or explosions are caused by the energy of nuclear fission [28], it can be considered that volcanic gases and volcanic products immediately after eruption have the nuclear fission products. But we cannot find the fission products [21]. Therefore, even if they are present in the volcanic products, they must be in an extremely small concentration. Consequently, the heat derived from the disintegration of radioactive elements in rocks seems not to be able to directly cause the volcanic eruption, but accumulation of such radioactive heat in the long time is considered to be possible to cause the volcanic activities. And the radioactivity of volcanic gases seems to arouse much interest on these problems.

5) - Summary

1. The radioactivity of a large number of volcanic gases from the craters, the fumaroles and hot springs in Japan is measured, and is never negligibly small, but often so large as comparable to that of the gases from the strongly radioactive mineral springs.

2. The existence of many radioactive elements such as Rn, RaA, RaB, RaC, Tn, ThA and ThB is confirmed in the volcanic gases, but An, isotope of Rn and Tn, is not yet found.

3. The variations of the radioactivity and the ratio (Tn/Rn) of volcanic gases are measured and the possibility for the detection of the variations of the volcanic activities is suggested.

4. The excessive distribution of Rn and Tn in the gas phase of fumaroles is a common phenomenon in the most fumaroles accompanied by hot waters in Japan. In many cases, these fumarolic gases are considered as the principal source of the radioactive substances in the hot spring waters situated closely to the fumaroles.

5. The mechanism of the introduction of the radioactive substances into the volcanic gases of fumaroles is discussed.

The cost of this investigation was defrayed from a grant given by the Scientific Research Encouragement Grant from the Department of Education, to which the authors wish to express their thanks.

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Volcanic Rocks of India

Volcanic activity both in the extrusive as well as associated hypabyssal forms such as dykes and sills has manifested itself in several parts of India during geological times. Our knowledge regarding the different palaeovolcanological epochs has been gathered mainly as part of the regional geological mapping in various parts of the country for over hundred years. Inevitably this knowledge is not exact, especially in the large terrains of the crystalline rocks of the Pre-Cambrian era, which comprise predominantly Peninsular India, where stratigraphy has been established in some well-mapped areas. Hence correlation between the formations in different Archaean terrains is tentative. The position is somewhat better when we come to later epochs when the age of the volcanic activities is fixed with the help of palaeobotanical and palaeontological evidence of the associated sediments. Some work has also been done in determining age of the volcanic rocks by radioactive methods, especially in the case of the Deccan traps. On the whole we have reasonable data regarding some of the main palaeovolcanological epochs in the geological history of India.

Peninsular India

Archaeans

The oldest rocks wherein volcanic activity is very well displayed are in Mysore, South India. During Lower Dharwar times, there was extensive volcanic activity when basaltic and andesitic lavas were extruded probably admixed with ash beds. These were succeeded by acid volcanic rocks such as rhyolites and keratophyres. Locally spilites, showing « pillow » structures indicating subaqueous conditions, have been noted. Later, acid dykes such as felsites and porphyries were intruded. During the next period, i.e., middle Dharwars volcanic products such as ashes and tuffs are associated with the metasediments.

Volcanic activity was extensively developed in the Chotanagpur area of Bihar and Orissa during Archaean times. In the Gangpur series, which are considered to be the oldest rocks in this region, presumably equivalent to the lower Dharwars of South India, tuffs are associated with the micaschists. During Iron ore series times (probably equivalent to middle Dharwars), basic lava flows and associated tuffs were formed. Later in the same period, the Dalma lavas were extruded associated with agglomerates. The Dhanjori lavas (overlying the Dhanjori quartzites) similar to the Dalma flows are presumably of the same age.

Minor volcanic activity is known during Archaean times in other regions of India. In Madhya Pradesh, massive traps and trappoids are associated with the rocks of the Chilpi Ghat series. In Rajputana, locally basic volcanic rocks are seen above the basal beds of the Aravalli system, considered equivalent to the lower and middle Dharwars of South India. The Khairamala amygdaloid represents renewed volcanic activity, the hypabyssal phase being seen as basic dykes in some parts of the region.

Late-Pre-cambrian

During late pre-cambrian times there was a renewal of volcanic activity in South India in the Cuddapah sedimentary basin. Associated with the sediments of the Lower Cuddapahs, basic sills are seen with possibly the dyke phase in the crystallines surrounding the basin. Not far from this basin, in Wajrakarur we have evidence of a volcanic plug seen as agglomerate with which are associated small specks of diamonds.

In Rajputana, during Delhi times (possibly equivalent to the Cuddapahs) there was extensive volcanic activity. Intrusion and extrusion of basic magma are recognisable in the lower and upper divisions, followed by the intrusion of the Erinpura granite. Post-dating this granite, there was extrusion of basic dykes, as also development of local volcanic centres in Sirohi (volcanic centre in Mudwara). At the end of the Delhis and also possibly in Lower Vindhyan times, the Malani acid lavas (rhyolites etc.) were extruded, followed by intrusion of basic dykes.

Associated with the Gwalior system in Gwalior (probably equivalent to the Cuddapahs) some traps are seen as sills and flows. The basic lavas and tuffs associated with the Bijawar series in Vindhya Pradesh and the Son valley are probably of the same age. In Panna, Vindhya Pradesh, we have diamondiferous pipes, presumably belonging to the same period.

During the succeeding Vindhyan times, intrusive dykes on a small scale came in the Son valley (intrusive into the Semris) and in Hyderabad (intrusive into the Bhima series).

Jurassic
Rajmahal and Sylhet Traps

Till we come to the middle or late Jurassic age, there is little evidence of any volcanic activity in Peninsular India. During middle Jurassic times volcanic activity occurred in the Rajmahal area in Bihar when the area was flooded with basic theolitic lavas. Locally, pitchstone flows have been reported recently. A lamprophyric phase of these lavas are seen as intrusive sills and also along fault planes in the Gondwana coal-fields of Bihar. These dykes are cut across by dykes of dolerite and basalt, equivalent to the Rajmahal lavas. In the Sylhet region of Assam, there are trap flows, presumably coeval with the Rajmahal traps and are similar in composition. Dolerite dykes of similar rock are also seen in the same region.

Cretaceous - Eocene
Deccan traps

Towards the end of the Cretaceous and also possibly during Eocene times, there was extensive volcanic activity when basic lava flows flooded the Deccan area comprising Bombay, Cutch, Kathiawar, Madhya Pradesh and Central India.

About 200,000 sq. miles of the area are now covered by trap reaching a maximum thickness of about 10,000 feet along the coast of Bombay. The traps have been divided into lower, middle and upper traps with the infratrappeans or Lametas at the base. Intertrappean beds and ash beds are associated with the traps. The age of the Deccan traps, which has been a subject of considerable controversy, is now considered, mainly on the evidence of fossil plants to be late Cretaceous-Eocene. Some radioactive measurements have also been done, the indicated age being 76-91 million years. The traps are predominantly basic in character, belonging to the Plateau-basalt type (theoleitic). In some parts especially in Bombay and Kathiawar, acid, intermediate and ultra basic rocks are seen, derived by differentiation from the original magma. In Kathiawar, there are plutonic masses such as the Girnar hills in which the earliest lava flows have been intruded by gabbro, diorite and monzonite and nepheline syenite, lamprophyre and basalt dykes (ring intrusions similar to those of the Tertiary Ring Intrusions in the islands west of Scotland). AUDEN's (1949) studies lead him to believe that the dykes common in Kathiawar, Konkan, and Gujrat are hypabyssal phases, later than the main lava flows and that they are not feeders to the lavas as originally conceived. In Cutch and Kathiawar, there was eruption of trap post-dating the formation of the plutonic foci. Dykes and sills belonging to the Deccan trap period are seen in the northern slopes of the Satpuras (CROOKSHANK 1936). Basic dykes probably of Deccan trap age are seen in the Gondwana fields of Rewa (Vindhya Pradesh).

Extra-Peninsular India

Our knowledge regarding volcanic activity in the extra-Peninsular India, comprising the Himalayan mountain chains, is vague because of the absence of detailed geological mapping. Correlation with the Peninsular rocks is difficult, especially regarding rocks of the pre-Cambrian age.

Pre-Cambrian volcanic epochs

In the Pir Panjal area of the Kashmir Himalaya, amygdaloidal trap rocks are associated with Dogra slates considered to be equivalent to the Purana rocks of Peninsular India.

Cambrian

Acid volcanic rocks (rhyolites and tuffs) were erupted during Cambrian times in Burma (Bawdwin volcanic series).

Carboniferous-Triassic

Panjal Volcanic series

From middle Carboniferous to upper Triassic times, there was wide-spread volcanic activity in the Pir Panjal area of Kashmir where agglomerates and pyroclastics and basaltic and andesitic lava flows are well seen. Upper Carboniferous lamprophyre dykes are known from the same area.

Late-Cretaceous

Volcanic activity again manifested itself in the Malla Johar area during late Cretaceous or Eocene times when lavas of andesitic and basaltic composition were erupted.

Recent

Volcanic activity is again manifest in geologically recent times in the Barren Islands and Narcondum in the Bay of Bengal, as well as in Baluchistan (Koh-i-Sultan).

Programme of work

During the field-season 1952-53 and the current field season, Officers of the Geological Survey of India have commenced a re-survey of the Rajmahal Traps in Bihar. Some detailed work on volcanic rocks is being carried out by the

Table showing Paleo-Volcanological epochs in India and adjacent countries.

	Peninsula	Extra-Peninsula
Recent		Volcanoes of Barren Island and Narcondum (Bay of Bengal) and in Baluchistan (Kon-i-Sultan).
Eocene Cretaceous	Deccan trap flows (basaltic). Plutons of Kathiawar; dolerite, basalt, and lamprophyric dykes.	Andesite and basalt flows in Malla Johar. Amygdaloidal basic lavas of Chandpur (Deccan traps).
Jurassic	Rajmahal trap flows (basaltic) (local) flows of pitchstone; dolerite and mica-peridotite dykes in the Gondwana fields of Bihar. Sylhet traps in Assam and basic dykes.	
Upper Triassic		Panjal volcanic series. Agglomerates and pyroclastics. Andesitic and basaltic flows.
Middle Carboniferous		Lamprophyres of upper-Carboniferous age.
Cambrian		Bawdwin volcanic series (acid) (Burma) Rhyolites and tuffs.
Late Pre-Cambrian.	*Andhra*: Dolerite sills in Cuddapah sediments with possible equivalents as dykes in the crystallines. Wajrakarur volcanic agglomerate. *Rajputana*: Basic sills and flows in lower and upper Delhis (Cuddapahs). Dolerite dykes of post-Erinpura granite age, as well as volcanic foci in Sirohi. During lower Vindhyan times Malani flows (acid, rhyolites). Later basic dykes. *Gwalior*: Traps and flows in Gwalior system. *Son valley*: Lavas and tuffs in Bijawar series. *Panna* (Vindhya Pradesh): volcanic plug (diamondiferous).	Trap rocks in Pir Panjal.
ARCHAEAN	*Mysore*: Basaltic and andesitic lava flows followed by acid volcanics (keratophyres, rhyolites and spilites) (lower Dharwars). Ashes and tuffs in middle Dharwars. *Chotanagpur*: Tuffs in the Gangpur series (? lower Dharwars). Tuffs and basic lava flows in the Iron-ore Series (? middle Dharwars). *Rajputana*: Local traps and basic dykes. *Madhya Pradesh*: Massive traps and trappoids associated with the Chilpi Ghat series.	

K. C. 22/2/54.

Mysore Geological Department and various Geology Departments of the Indian Universities.

Acknowledgment

The writer is thankful to Dr. M. V. N. Murthy, Geologist, Geological Survey of India, for the assistance rendered in preparing this report. Thanks are also due to members of the Paleovolcanology Committee for their co-operation.

Important informations on the different Palaeo-Volcanological epochs in India are contained in the following publications:

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E. AUBERT DE LA RÜE

Sur les différentes séries de laves et les roches intrusives associées de la Péninsule Courbet (Archipel de Kerguelen)

(Avec 5 planches)

Dans un ouvrage antérieur (1), j'ai donné un premier aperçu d'ensemble de la nature géologique de l'archipel de Kerguelen, à la suite de deux campagnes réalisées en 1928-29 et 1931, et montré l'origine exclusivement volcanique de cette terre subantarctique. Depuis, en 1949-1950 et de 1951 à 1953, j'ai plus spécialement étudié la Péninsule Courbet, qui correspond à la partie orientale de la grande terre, demeurée hors de mes précédentes reconnaissances.

Plusieurs séries de lave ont pu être identifiées, dans l'ensemble comparables à ce que l'on connaît dans le reste du groupe.

Les épanchements les plus anciens sont représentés par des roches fortement altérées habituellement et ayant les caractères des spillites. Ce sont des roches verdâtres en général, souvent épidotisées et pyritisées. Les unes sont compactes, d'autres vacuolaires, les vacuoles étant remplies par de la calcite, de la silice et des zéolites. Parmi les laves dont la nature primitive est encore reconnaissable, on note principalement des basaltes, souvent porphyriques et des andésites. Cette ancienne série comprend également des tufs bréchoïdes et des conglomérats très durs et d'une grande cohésion, dont les éléments volcaniques sont parfaitement roulés.

Ces matériaux volcaniques affleurent en place, entre les cotes 300 et 750, au centre du secteur montagneux occupant la partie occidentale de la péninsule. Ils forment plusieurs reliefs, comme les Montagnes Vertes et les Mamelles, se dressant juste au Nord du Val Studer. Ces spillites occupent probablement une place importante dans le socle de l'archipel, mais elles n'avaient jamais été observées en place. Jusqu'à présent, je ne les connaissais qu'à l'état erratique dans le centre et l'Ouest de l'archipel. Ce que l'on sait de la progression des glaciers, à l'époque quaternaire, ne permet pas de penser que les fragments épars de laves anciennes, rencontrés dans les moraines des plateaux plus à l'Ouest, puissent provenir des affleurements de la péninsule Courbet. Il doit donc en exister d'autres, encore non reconnus, peut-être recouverts par les glaciers qui conservent une large extension dans l'Ouest (Icefield de Cook notamment).

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(1) *Étude Géologique et Géographique de l'Archipel de Kerguelen.* Revue de Géographie Physique et de Géologie Dynamique. Vol. V, Fasc. 1 & 2, Paris 1932.

L'âge de ces anciennes éruptions demeure imprécis. Peut-être datent-elles du Secondaire ? Elles sont en tous cas antérieures aux grands épanchements basaltiques fissuraux, subhorizontaux, qui forment actuellement la masse principale de l'archipel. Ces laves de caractère spillitique ont été envahies par des sills de roches intrusives diverses, à l'exclusion de granite, et représentées principalement par des syénites, des monzonites, des diorites et des gabbros. Ces roches, accompagnées de syénites néphéliniques, sont particulièrement bien exposées sur les pentes orientales des Montagnes Vertes, entre les cotes 500 et 700. Ces intrusions sont cantonnées dans les spillites, mais j'ai retrouvé des fragments de certaines d'entre elles dans des coulées et des filons basaltiques appartenant à des épanchements plus récents, notamment dans le ravin du Mica, proche du lac Studer.

L'ensemble de la péninsule Courbet est principalement formé par une puissante superposition de nappes basaltiques d'origine fissurale, dont les empilements dépassent 1.000 m. d'épaisseur au dessus du niveau de la mer au mont Crozier (1.040 m.), point culminant de la région. Tous les autres sommets principaux de la région, oscillant entre 800 et 1.000 m. sont le résultats de grandes fractures et de l'érosion, qui ont morcelé et dégradé ces puissants entablements basaltiques.

Ces basaltes fissuraux présentent une assez grande diversité de structures et de compositions. Les uns sont très riches en olivine, d'autres sont surtout feldspathiques et correspondent à des labradorites et à des andésites. Certaines coulées sont compactes, d'autres vacuolaires et souvent riches en cristaux de chabasie (mont Amery, massif du Chateau, anse des Cascades). Ces épanchements fissuraux ont été accompagnés localement de phénomènes explosifs, signalés par la présence de tufs, fins ou grossiers, souvent rubéfiés, particulièrement fréquents dans le massif du Chateau, où l'on voit également des accumulations de scories stromboliennes, avec bombes spiralées, intercalées entre des nappes de basalte.

Dans la partie orientale, basse et plate, de la péninsule, recouverte de puissants dépôts morainiques et de tourbières, le substratum volcanique est peu visible. Je l'ai cependant découvert en divers points, principalement le long de la côte et dans certains lits de torrent. Ces divers affleurements correspondent pour la plupart à des basaltes, de divers types. Ils ont, dans l'ensemble, des caractères physiques qui les distinguent des grands entablements basaltiques de la zone montagneuse.

À Port-aux-Français, de même que sur la rive nord de la baie Norvégienne, apparaissent des basaltes homogènes, d'un grain extrêmement fin, ayant acquis une structure schisteuse et qui ont subis des déformations structurales. J'ai retrouvé, par la suite, ce type très particulier en certains points du secteur montagneux (Lac Studer, à l'Ouest du Lac Margot, etc...). Il appartient donc bien à la série fissurale, que la présence de minces couches de lignite et d'argile gréseuse, avec restes de végétaux, intercalées entre certaines coulées (à la partie supérieure de la vallée débouchant à la baie Bailey) permet d'attribuer avec assez de vraisemblance au Miocène.

Les laves les plus habituelles des plaines orientales sont des basaltes à olivine très vitreux, qui présentent habituellement un débit prismatique fort net, ce que l'on ne voit guère dans les coulées fissurales des montagnes. Les escarpements de la presqu'île du Prince de Galles offrent, en particulier, d'excellents exemples de ces colonnades basaltiques, dans certaines desquelles sont ouvertes des grottes marines (Pointe Suzanne). Une particularité de ces basaltes vitreux est la présence très commune d'enclaves de péridotite et de gabbro.

La corrélation entre ces basaltes vitreux et ceux de la grande série fissurale n'apparaît pas clairement, mais je suis enclin à les considérer comme plus récents. Cette hypothèse s'appuie sur la présence d'un petit cône volcanique, encore très reconnaissable bien qu'assez mal conservé: le mont Peeper (200 m) qui surgit isolé dans les plaines. Sous les projections scoriacées, renfermant souvent des agrégats d'olivine associée à un pyroxène chromique, qui ont participé à l'édification de ce volcan, apparaissent des basaltes vitreux très semblables à ceux du promontoire du Prince de Galles. Ce cône est antérieur en tous cas à la glaciation pléistocène, car les glaciers ont déposé sur son sommet des blocs erratiques de basaltes plus anciens, provenant des montagnes situées un peu à l'Ouest.

Quelques pointements de phonolite surgissent en de rares endroits dans la région des plaines et du promontoire du Prince de Galles, antérieurs, semble-t-il, à l'épanchement des basaltes vitreux. Tel est le mont Bungay (67 m), modeste éminence de forme conique et quelques pitons escarpés dominant la rive méridionale de la baie Norvégienne. L'un d'eux montre un débit prismatique tout à fait remarquable, les prismes affectant une disposition en gerbe.

Dans le secteur montagneux, je n'ai observé aucun affleurement de phonolite, roches qui ont une grande extension en d'autres parties de l'archipel, mais les filons trachytiques sont assez communs de part et d'autre du Val Studer.

Dans les Montagnes Vertes ces dykes de trachyte se suivent sur de longues distances mais sont très étroits, de quelques mètres à peine. Ils recoupent également les spillites et les intrusions de roches grenues qui ont envahi celles-ci. On les retrouve plus à l'Ouest, de l'autre côté du Val Studer, où ils traversent les basaltes fissuraux miocènes (?) du mont Crozier.

De très nombreux filons de basalte, que l'érosion a souvent dégagés et fait apparaître en relief, se sont insinués dans les multiples cassures affectant les basaltes fissuraux. À première vue, la lave de ces filons est assez banale, mais certains d'eux sont d'un intérêt très particulier. Tels sont ceux qui recoupent le ravin du Mica, juste au Nord du lac Studer, remarquables par les énormes cristaux de hornblende et de biotite, ces derniers pouvant atteindre 5 à 6 cm de diamètre, qu'ils renferment en abondance. Quelques uns de ces filons contiennent également des agrégats d'olivine associée à du pyroxène chromique et également des enclaves de trachyte micacé, du type de ceux des Montagnes Vertes, qui se dressent d'ailleurs à peu de distance de là. Ces filons d'un type spécial, traversant ici les basaltes horizontaux, m'ont semblés les laves les plus récentes de la région montagneuse. Ils s'apparentent à d'autres qui affleurent en certains points du promontoire du Prince de Galles, région distance d'une trentaine de kilomètres au Sud-Est, où tout porte à croire qu'ils sont liés génétiquement aux émissions de basalte vitreux à olivine.

Telles sont, sommairement exposées, les principales observations faites sur le terrain et intéressant la succession des phénomènes volcaniques dans la partie orientale de l'archipel de Kerguelen. Cette reconnaissance a permis de constater l'absence complète de manifestations volcaniques actuelles, même sous leurs formes les plus atténuées.

PLANCHES

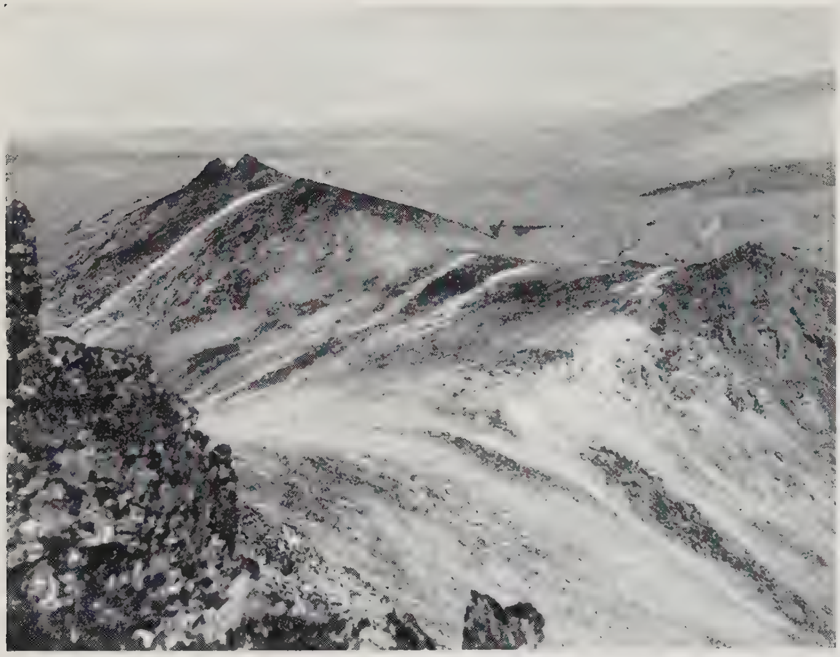

Fig. 1. - Le sommet des Montagnes Vertes (Alt. 750 m.), formé par les laves anciennes, que recoupent des filons de trachyte (apparaissant en traînées blanches).

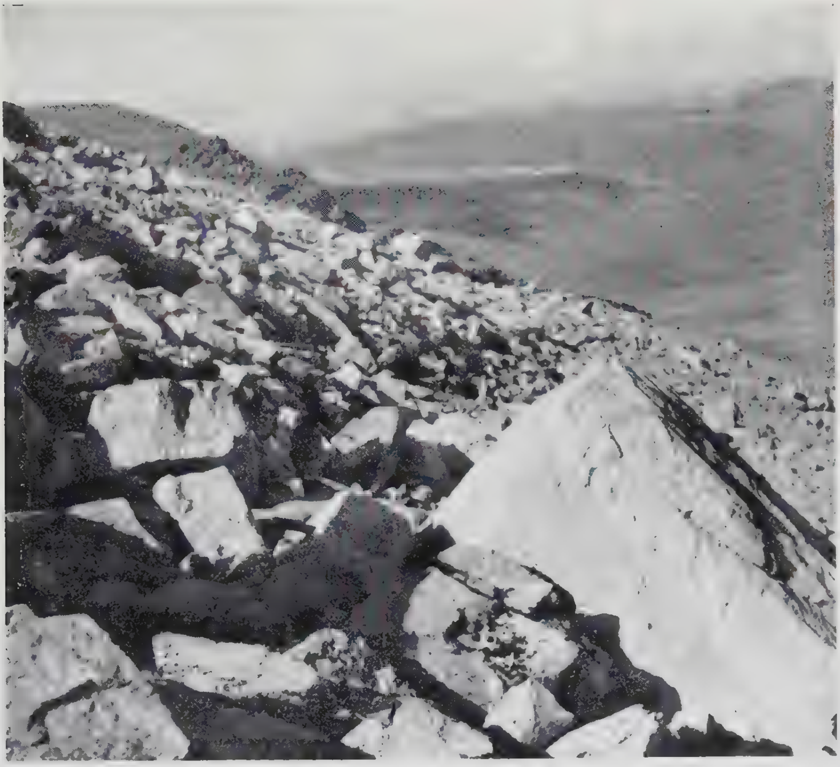

Fig. 2. - Sill de syénite néphélinique, désagrégé par le gel, envahissant les laves anciennes sur les pentes orientales des Montagnes Vertes.

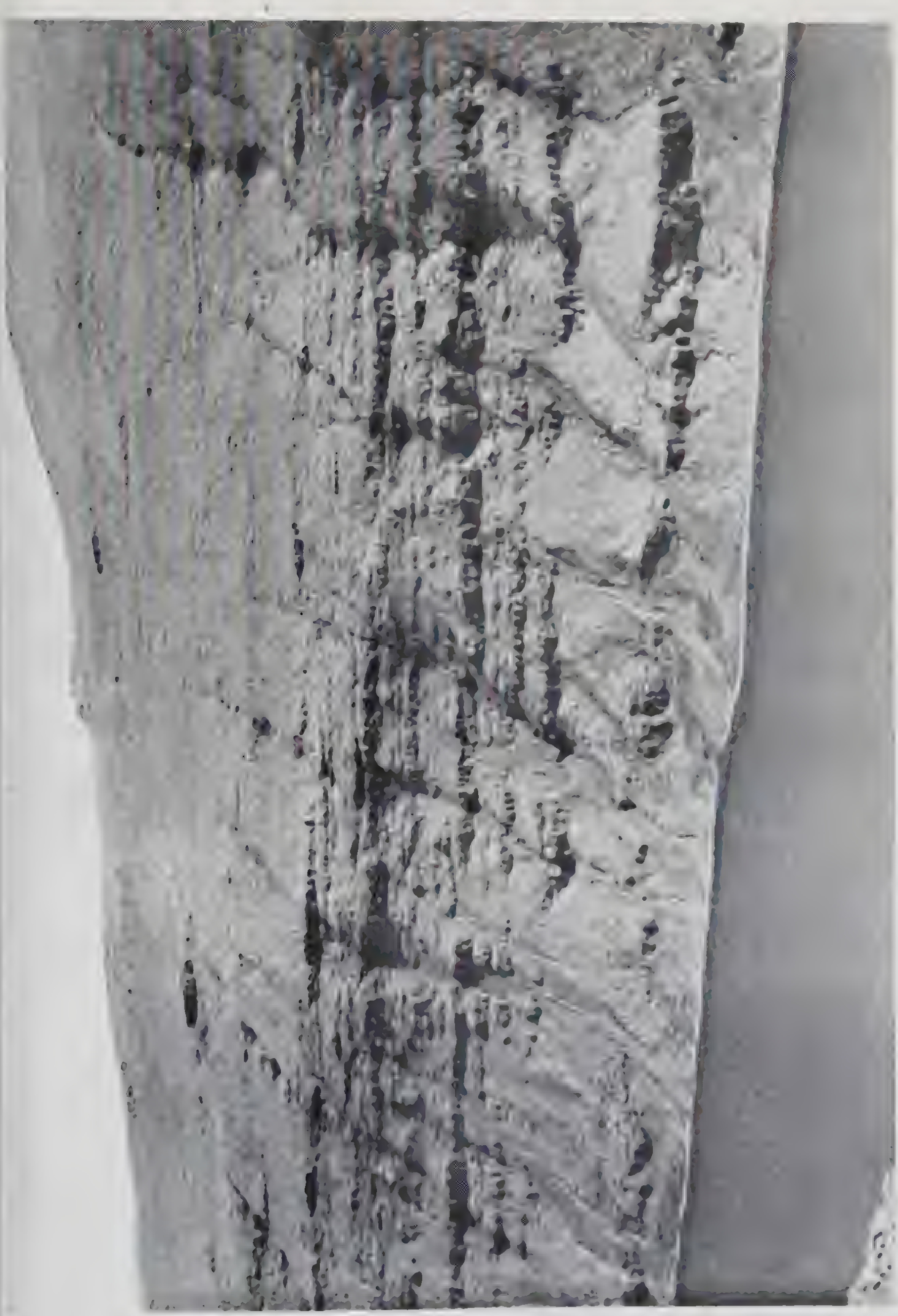

Fig. 3. - Basaltes fissuraux sub-horizontaux (Miocène ?) le long du lac Studer.

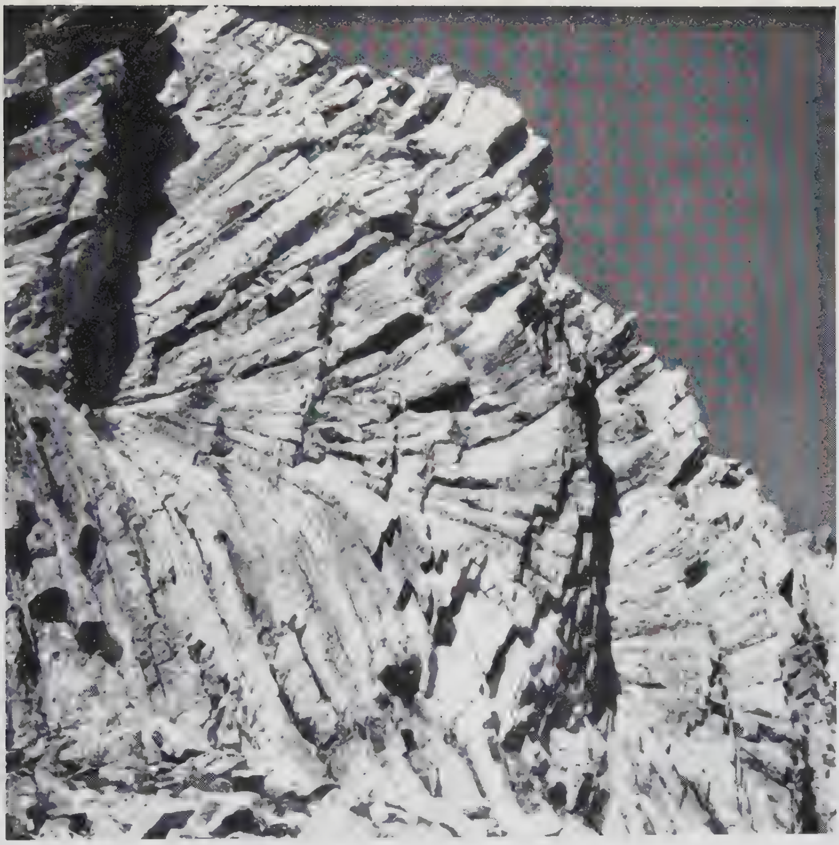

Fig. 4. - Débit prismatique des phonolites d'un piton du Promontoire du Prince de Galles.

Aubert de la Rüe — *Sur les différentes séries de laves et les roches intrusives associées de la Péninsule Courbet (Archipel de Kerguelen).*

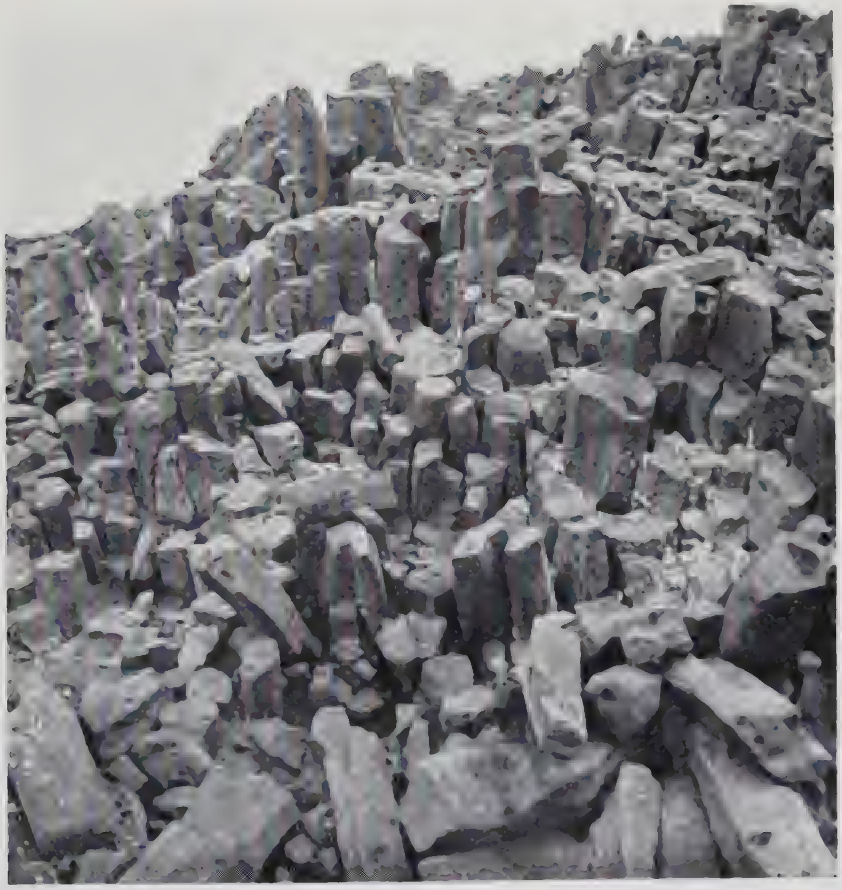

Fig. 5. - Basalte vitreux prismé de la série récente. Pointe Suzanne.

YEHIA ANWAR
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A Xenolith with abnormal Biotite in the Lava of Ischia

(With 2 text-figures and 1 plate)

Introduction

During the petrological studies of the Ischian lavas, xenolithic blocks have been encountered among the scories of Arsoite, trachyte flow of 1301. One type of these blocks is a biotite bearing rock which was described briefly for the first time by A. Rittmann (1948, pp. 678-79). He directed, however, the attention to the probable significance of these blocks in throwing some light on the physical conditions that prevailed before and during the consolidation of the enclosing lava.

A detailed study was accordingly carried out by the present writer on a specimen of the biotite bearing type of xenolithic rock, which was kindly offered by Professor A. Rittmann. For this the rock was chemically analysed and the biotite in the rock was optically and chemically.

Petrography of the Xenolithic Rock

The xenolithic rocks of this type are generally rare. Commonly they are irregular in form, mostly rounded, and are of an average diameter of about 20 cms. The most striking feature of these rocks is that they occur as loose blocks quite separable from the walls of the enclosing cavity.

In hand specimen the rock is brown in colour and of uniform fine grained texture. It shows on fracturing shining surfaces due to the abundance of flakes of biotite and haematite.

Under the microscope, the rock is seen to be highly porous, the pore spaces constitute about 30 percent of the rock. The essential constituents are plagioclase, diopsidic pyroxene, biotite and iron ore. Apatite and glass are also present (fig. 1 and plate I).

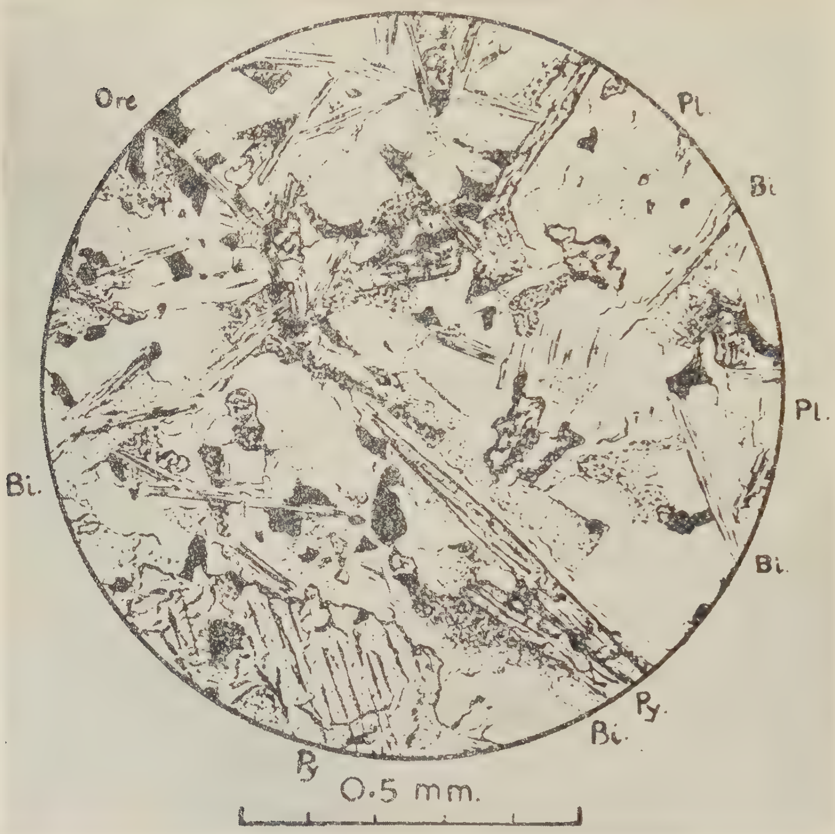

Fig. 1.

The plagioclase is perfectly fresh and occurs dominantly as thin elongated and twinned laths, up to 0.5 mm long. These laths may occur solitary or in groups with occasional stellate fashion. A few crystals may show microporphyritic tendency, 0.8 mm in maximum length, and enclose grains of pyroxene and iron ore along its cleavage plains. In some cases the inclusions are of fine dust of brownish glassy material which is arranged zonaly along the crystal outline. In contrast to the fine lath shaped crystals, the microphenocrysts show embayed bounderies against the pyroxene microphenocrysts. The composition of the plagioclase is found to be nearly uniform, bytownite of 70-75 % An. Sporadically, there are limpid untwinned fine allotriomorphic grains of alkali-felspar that occur interstitially among the other constituents.

TABLE 1

Chemical Analysis of the Xenolithic Rock.

	Wt %	Niggli Equivalent Norm				Niggli Values	
		Basis Norm		Katanorm			
SiO	48.47	Q	24.1	Or	10.8	Si	119
Al_2O_3	16.71	Kp	15.0	Ab	22.9	al	24
Fe_2O_3	8.07	Ne	17.5	An	15.1	fm	34
FeO	1.89	Ns	3.5	Ne	5.9	C	24
MgO	4.13	Cal	11.2	Wo	8.0	alk	18
CaO	9.03	Cs	6.3	En	1.3	K	0.38
Na_2O	4.56	Fo	8.6	Ac	3.4	mg	0.44
K_2O	4.26	Fa	2.5	Bi	27	ti	3
H_2O+	0.80	Fs	8.6	Tit	0.6	p	0.89
H_2O-	0.05	Cp	1.7	Mt	3.2		
TiO_2	1.50	Ru	1.0	Cp	1.7		
P_2O_5	0.90	Q	22.9				
MnO	0.15	L	45.8				
	100.52	M	29.6				

Mode: (Vol%)

Plagioclase	37%
Pyroxene	20
Biotite	27
Ore	9
Apatite, glass, and alkali-felspar	7

The pyroxene occurs dominantly as fine rounded grains and short prisms, 0.1 mm. in diameter. Microporphyritic crystals are also present, 0.5 mm. in maximum diameter, but are of subordinate amounts. They are of brownish tinge and may occasionally enclose grains of iron ore. The pyroxene in the groundmass is an aegirine augite and is generally of a deeper greenish colour than the microphenocrysts. In some crystals the greenish colour becomes deeper at borders than at the center, which is most probably due to zonal variation in composition, being more alkaline at the borders. The average composition of the pyroxene, as indicated by the optical properties, $2V_\gamma = 58^0$ (± 2) and $C/\gamma = 42^0$, is WO_{48} EN_{37} Fs_{15} i.e. diopsidic augite.

The biotite forms irregular flakes and thin elongated shreds of about 0.1 mm. in length, but it occasionally attains 1.4 mm. length. It is occasionally seen to associate closely the pyroxene where it occurs along the borders of the crystals and usually is accompanied by iron ore. Such features suggest reaction relation between the two minerals. The biotite is strongly pleochroic with γ = deep brown, β = reddish brown and α = dark brownish green. It has an abnormally large optic axial angle, 40^0 $(+ 2)$ and strong dispersion, $r < v$.

Isotropic glassy material of brown colour occurs interstitially and is usually charged with ore. Under high power magnification microlites of felspar in parallel arrangement could be seen in some parts of the glass. The refractive index of the glass is found to be $n = 1.52$, which corresponds to a trachytic composition (George, 1924).

From the inter-relationships between the present minerals it seems that the iron ore and apatite were the earliest minerals to be formed. Most probably the pyroxene was formed later than the plagioclase but at a stage at which only little of the plagioclase was formed. The biotite seems to have started at a much late stage in the crystallisation period of the pyroxene.

Chemical analysis of the xenolithic rock is given in table 1. The approximate mode and norm calculated according to the Niggli system (Burri and Niggli, 1945) are also included. The analysis shows that the ferric iron is strikingly higher than the ferrous iron. It is most probable that the rock is highly oxidised and a part of the ferric iron is contained in the ferromagnesian silicates, biotite and in the pyroxene as acmite molecule.

Chemical Composition and Optics of the Biotite.

The optic axial angle was determined by direct reading on the universal stage using sodium light. For the dispersion, a variable monochromator was used and the optic axial angle for each wave length was determined directly on the universal stage. This relation is diagramatically shown in fig. 2. The refractive indexes n_γ and n_β were measured by the immersion method in sodium light.

TABLE 2

Chemical Composition and Optical Properties of the biotite.

Analysis		Molecular proportions	No. of metals on basis of 12
SiO_2	38.47	0.6380	2.83
Al_2O_3	11.63	0.1138	1.01
TiO_2	4.12	0.0514	0.23
Fe_2O_3	14.12	0.0884	0.78
FeO	2.54	0.0353	0.16
MnO	0.14	0.0020	0.09
MgO	13.26	0.3289	1.46
CaO	2.56	0.0456	0.20
Na_2O	1.59	0.0256	0.23
K_2O	8.56	0.0909	0.81
H_2O+	3.44	0.1909	1.69
	100.43		

Formula:

$(O, OH)_{1.69}(K, Na, Ca)_{1.24}(Mg, Mn, Fe'', Fe''', Ti)_{2.72}(Si, Al)_{3.81}$

Specific Gravity: 2.98

2V : 40°(± 2)

γ : 1.692 (± .002)

β : 1.683

$r < v$

The results of the chemical analysis and the optical properties of the biotite are given in table 2 together with the calculated formula of the biotite.

The analysis of the biotite agrees well with the general formula for micas as proposed by Berman (1937), $W\ (X, Y)_{2\text{-}3}\ Z_4\ O_{10}\ (O, OH, F)_2$, in which W = Ca, K, Na; X = Mg, Fe, Mn, V, Al; Y = Al, Fe, Ti and Z = Si.

The number of metals plus silicon is 7.7 and thus the biotite belongs to the octophyllites (Winchell, 1925). Moreover, as the value of the X group, 2.7, approaches the higher limit of this group, the biotite is of phlogopitic affinity.

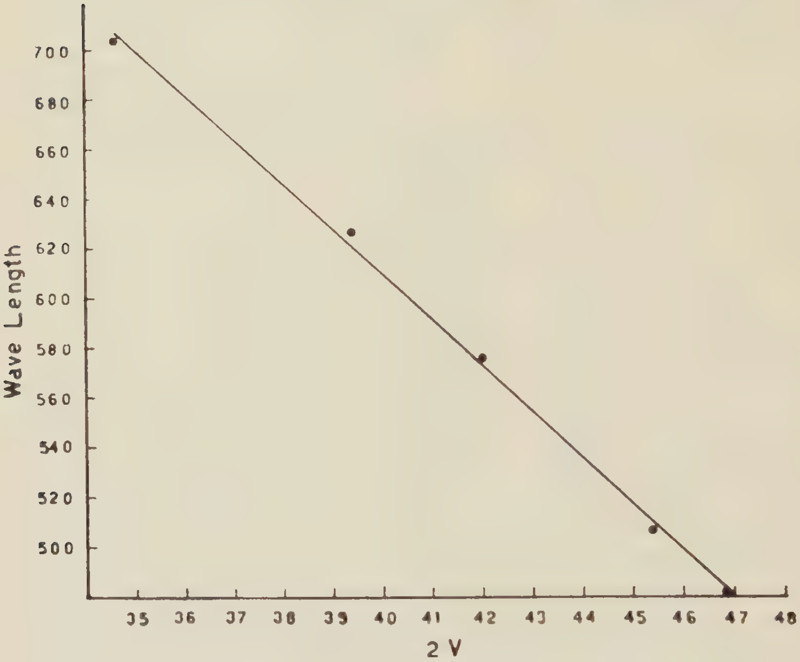

Fig. 2.

Other features of the analysis are the replacement of Ca for K and Na and that Al replaces about one third of Si in the tetrahedron. The aluminium may be joined by Ti in replacing Si in order that the Y group becomes 4. Such a replacement has been shown to be possible in titanium rich silicates. (Sahama and Rankama, 1949, p. 561).

The biotite carries quite a large quantity of ferric iron. The possible effects of such high state of oxidation of iron in biotite is not well known. Winchell (1946) and Heinrich (1947) have shown that oxidation affects the optical properties of the biotite. However, it is found difficult to estimate this effect because of the presence of ferric iron as a common constituent and it has also been shown that it may exceed ferrous iron in case of biotites of the volcanites.

The chemical data about biotites of large optic axial angle are scanty. In table 3, a number of chemical analyses of biaxal biotites are given for comparison. In the same table is also included the number of cations calculated for each analysis on the basis of 12 (O, OH). On attempting to correlate between the size of the optic axial angle and the composition, it is found that the only evident relation is the direct variation of the optic axial angle with ferric iron.

	A	1	2	3	4
$\frac{Fe'''}{Fe''' + Fe''}$	0.79	0.60	0.61	0.24	0.22
2V	40°	20-25°	18°	11° 26′	5°

TABLE 3

	A	1	2	3	4
SiO_2	38.47	37.53	39.16	34.03	35.90
Al_2O_3	11.63	14.74	17.55	18.46	12.17
TiO_2	4.12	1.51	0.64	2.74	3.89
Fe_2O_3	14.12	4.93	9.97	2.01	4.23
FeO	2.54	3.02	5.66	21.54	13.58
MnO	0.14	0.33	—	—	0.62
MgO	13.26	21.83	15.16	8.06	12.16
CaO	2.56	0.15	—	0.50	2.55
Na_2O	1.59	0.92	2.79	0.34	3.28
K_2O	8.56	10.35	5.66	8.88	7.28
H_2O	3.63	4.78	2.50	3.29	3.80
P_2O_5	—	—	0.62	—	1.16
Cr_2O_3	—	—	—	—	—
Li_2O	—	—	—	0.04	—
F	—	—	0.78	0.25	—
	100.62	100.09	100.49	100.14	100.62

TABLE 3 (cont.)

	A	1	2	3	4
Sp. G;	2.98	2.94-2.98	—	—	—
2V	42°	20-25°	18°	11° 26′	5°
γ	1.692—	—	—	1.5887	—
β	1.683	1.61-1.62	—	—	1.630
α	—	1.56-1.57	—	1.6311	—
Dispersion	r < v	r < v	—	—	—
N° of Metals on Basis of 12 (O, OH).					
Si	2.83	2.68	2.94	2.62	2.73
Al	1.01	1.24	1.56	1.68	1.09
Ti	0.23	0.08	0.04	0.16	0.23
Li	—	—	—	0.01	—
Fe‴	0.78	0.27	0.56	0.12	0.25
Fe″	0.16	0.18	0.36	1.39	0.87
Mn	0.09	0.02	—	—	0.04
Mg	1.46	2.33	1.70	0.93	1.40
Ca	0.20	0.01	—	0.04	0.21
Na	0.23	0.13	0.40	0.06	0.49
K	0.81	0.95	0.54	0.87	0.71
H	1.69	2.28	1.26	1.70	1.94
F	—	—	0.37	0.12	—

A. Biotite from the xenolithic rock, new analysis by Y. Anwar.

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4. Biljon, V. S. (1939). *The Kuboos Batholith, Namaquland.* Trans. Geol. South Africa, Vol. XIII, pp. 123-219.

In general, the geological environment seems to have an important effect on the optical properties of the biotite. Biaxal biotites have been frequently described from effusive rocks, but these were generally resorbed, thus indicating an early stage of formation prior to extrusion. In contrast, the present biotite is perfectly fresh and uncorroded, thus suggesting that it was in equilibrium with the other present phases and its formation is related to the particular crystallisation environment. Accordingly, it seems worthwhile to consider the nature of the xenolithic rock on the light of its textural and mineralogical features.

General Remarks on the Nature of the Xenolithic Rock.

Two possibilities may be considered concerning the original nature of the xenolithic rock:

1. Igneous origin. — The nearest approach to this rock is a tephritic composition. However, such a rock when enclosed in a trachytic lava (Arsoite) would lead to much different results. Thus the albitisation of the plagioclase would be the normal consequence rather than the present calcic plagioclase of An_{75}, as well as the amphibolitisation of the pyroxene. Moreover, the highly vesicular nature of the rock and its occurrence as loose fragments in its cavities would favour a more reactive nature of the xenolith rather than a rock of igneous origin.

2. Sedimentary origin. — Such an origin is probably the one that can account for the textural feature and the mineral composition of this rock. A correlation might probably be made between the composition of this rock and a calcareous shale or marl. Under the effect of metamorphism and metasomatism, such a chemically contrasted sediment would account for the basic plagioclase and the diopsidic pyroxene ($Wo_{48}\,En_{37}\,Fs_{15}$) in the rock. The rocks so called Marna (epomeotuffites) have a composition comparable to a calcareous shale or marl, being a mixture of trachytic tuff and calcareous mud. These rocks are found in the vicinity of Arso and constitute a distinct formation older than the Arsoite flow. It is likely that these xenolithic rocks represent fragments torn from this formation at the time of its ascent.

The effect of rising temperature, in the early stages, on a xenolith of such a sediment would be the expulsion of CO_2

which results in the shrinkage of the rock and production of the porous texture. Such an environment of high temperature combined with low pressure has been shown to be the most favourable condition for the dissociation of limestone (Zambonini, 1935, p. 66). The rising temperature would also facilitate the subsequent permeation of the xenolithic rock with the metasomatising solutions emanating from the enclosing lava.

The formation of the pyroxene and biotite was probably controlled by the vapour pressure produced in the xenolithic rock during the distillation of the vapour phase from the magma at relatively later stages, i.e. at lower temperature. It is well known that under high vapour pressure the pyroxene is unstable and instead a hydrated phase is formed; this would be compatible with the observed relations between pyroxene and biotite, the latter being of late stage of formation. Another factor connected with the formation of the biotite is the progressive increase of K_2O during the late stages. It is interesting to notice that the hydrated phase formed is biotite rather than hornblende, which also agrees with the view that the increase of K_2O favours the formation of the sheet structure as it would accomodate the large ion of potassium (Bowen, 1928, pp. 79-85).

It is difficult, however, under the present state of knowledge to follow the changes that took place in the evolution of the different phases in the xenolithic rock. In fact, the present studied specimens do not carry any imprint of their past history and further investigation of more specimens, when available, would help in throwing more light on the origin of these xenoliths.

It may be concluded that the observed characters of the biotite are a reflection of the physico-chemical conditions that prevailed during its formation, which are essentially pneumatolytic action at low temperature.

The writer desires to thank Professor Dr. A. Rittmann for providing the studied specimens and for his helpful criticism in connection with this work.

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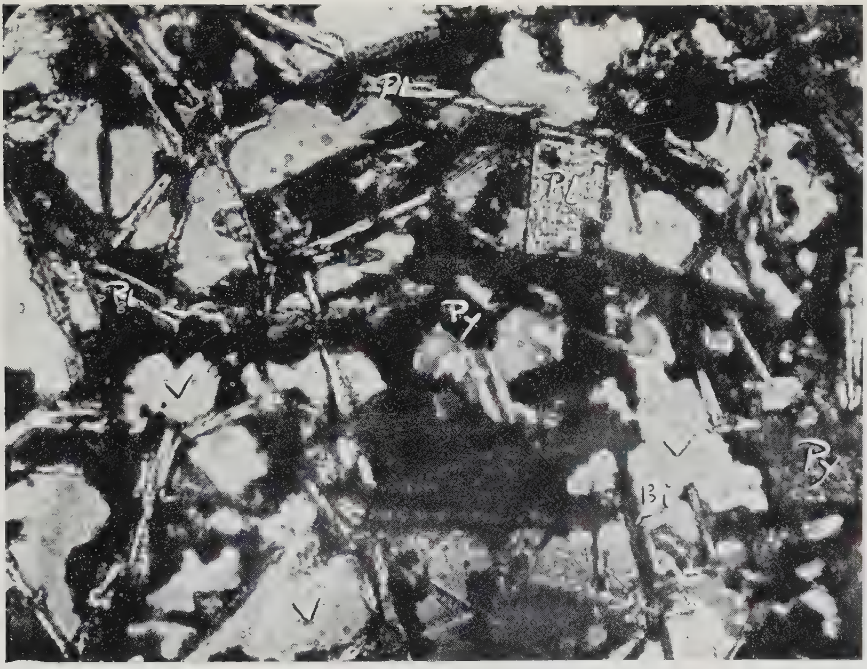

Photomicrograph of thin Section of the Xenolithic rock showing: V = empy vesicles, Pl = plagioclase, Py = pyroxene and Bi = biotite. Ordinary light. X 70.

LUDOVICO SICARDI

La Solfatara di Pozzuoli

(Con 8 tavole)

Tra i numerosi crateri dei Campi Flegrei, sul golfo di Napoli, quello della Solfatara di Pozzuoli è l'unico che da oltre due millenni almeno conserva un'attività fumarolica con tutta probabilità mai interrotta. Nel 1538 a qualche chilometro di distanza si è avuta l'apertura di una nuova bocca vulcanica che nel giro di quarantotto ore creò il suo edificio, il M. Nuovo, alto 140 m., ma di quello sfogo eruttivo di così breve durata non rimane oggi che qualche debole spiraglio fumarolico. Le fumarole della Solfatara di Pozzuoli invece rivelano, pur nella non eccessiva termicità dell'esalazione, una persistenza veramente insolita giacchè è piuttosto abituale nei centri vulcanici l'alternarsi di fasi di diversa attività.

Con il nome di « Solfatara » si identifica il cratere più che l'edificio vulcanico. La parte più alta della cintura craterica è in realtà il M. Olibano (m. 199), che il Rittmann ha mostrato essere una cupola lavica preesistente all'edificio della Solfatara. La formazione di quest'ultimo, che il De Lorenzo ritiene avvenuto per un unico violento atto esplosivo, ha rovinato il lato NW della cupola, la quale è rimasta in parte incastrata nella nuova costruzione del cui cratere costituisce l'appesa parete di SE.

Nella cartina è riportato un mio recentissimo aggiornamento della fossa craterica della Solfatara con il rifacimento della topografia del fondo, localizzando in questo le diverse manifestazioni fumaroliche riconoscibili come singoli elementi o gruppi caratteristici. A illustrazione della cartina questa nota vuol dare una succinta descrizione della Solfatara nei suoi più interessanti aspetti attuali e trascorsi per un rapido sguardo su questo vulcano, che, se non è dei maggiori, anche nella modesta ampiezza della propria fenomenologia racchiude motivo di interesse nel più vasto campo di studio dell'intera regione vulcanica flegrea di cui la Solfatara costituisce oggi l'elemento più vivo. Per maggiori dettagli e per la bibliografia, di cui qui riporto solo le note più significative, rimando a due altri miei lavori.

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La piana craterica ha una superficie di poco meno 18 ettari con un diametro E-W di 550 m. ed uno NNW-SSE di 500. A sud, presso l'ingresso a livello del fondo craterico, cui si giunge direttamente dalla strada carrozzabile, è un caposaldo della livellazione di precisione eseguita dall'Istituto Geografico Militare nel 1922 ed al quale corrispondono le coordinate geografiche :

lat. Nord	40° 49′, 6
long. Est M. Mario	1° 41′, 1

La carta dell'I. G. M. porta segnata nel settore di NE la più bassa quota del fondo craterico (92 m.). A q. 100 circa si innestano le pareti crateriche il cui circuito ha un orlo che ad W è appena di pochi metri sopra la piana, ma che si porta quindi sui 150-175 laddove la cintura si è venuta ad addossare su quella del cratere di Agnano, alla cui formazione quindi quella della Solfatara risulta posteriore, e raggiungendo i 199 m solamente per la presenza della cupola trachitica di M. Olibano.

La natura vulcanica del luogo si rivela sopratutto nel settore di SE, parzialmente negli altri. Il terreno in tale zona è caldo ed al mattino vi si scorgono moltissimi spiragli fumarolici la gran parte dei quali, alimentata da una debole esalazione, sparisce facilmente con l'elevarsi della temperatura, rimanendone visibile un numero assai ristretto. La zona più meridionale di questa porzione del fondo craterico, addirittura spoglia d'ogni traccia di vegetazione, è chiamata il « Piano

Sterile ». Su quest'ultimo è aperta la fossa della cosiddetta « Fangaia », un pseudovulcanetto fangoso. Il restante è cosparso di arbusti più o meno radi, i quali poi cedono rapidamente, specie nel settore di NW, ad una vegetazione rigogliosa che sembrerebbe ricavare tanta ricca vitalità dal tiepido umidore che senza dubbio si allarga sotto di essa.

La fascia delle maggiori fumarole si trova in posizione tale, come appare dalla cartina, da sembrare indicare una particolare via d'uscita, trovata e mantenuta dalla massa dell'esalazione vulcanica seguendo la superfice di discontinuità tra il tappo del condotto e la parete craterica. Penso che siffatta caratteristica possa bensì derivare dall'ingombro caotico del materiale occludente il condotto, in parte ricadutovi con le esplosioni ed in parte franato dal M. Olibano, ma che tanta accentuazione a levante derivi pure dal rapporto genetico esistente tra la Solfatara ed il vicino e più vecchio cratere di Agnano. Non mancano infatti i residui di attività fumarolica in quest'ultimo, laddove il recinto interferisce con quello di levante della Solfatara.

Le fumarole della Solfatara appaiono dunque sopratutto lungo il bordo di SE e di NE. Di queste si possono fare tre gruppi: quello centrale ad est con la grossa fumarola della « Bocca Grande » e serpeggiante anche verso l'alto; più a sud, a levante del Pozzo, la cosiddetta « Piccola Solfatara » e verso nord il ridottissimo nucleo delle « Stufe », cui segue del tutto distanziata la fumarola isolata della « Pietra Spaccata ».

Tra tutte queste fumarole predomina quella della « Bocca Grande » dalla quale fuoriesce, impetuosa più che altrove, una massa gassosa solfidrico-carbonica come le altre, commista ad abbondante vapor acqueo ma i cui valori termici nell'ultimo sessantennio hanno oscillato tra 141° e 164°, con due punte massime di 174° 5 nel 1927 e di 215° nel 1935. Le fumarole minori mostrano di solito una temperatura di 99° - 99° 5 e solo tra il 1921 ed il 1927 il Signore vi ha potuto ripetutamente misurare dei massimi di 105° - 110°. Se si osserva la serie delle misure termometriche effettuate alla Bocca Grande dal 1889 al 1939, ho già mostrato nella mia prima nota del '42 come, a prescindere dai due massimi valori soprariportati, sia da riconoscere tra il 1908 ed il 1935 una media di 160° (massimo 163° 8), mentre nell'intervallo precedente si trova 154° (massimo 157°) e nel successivo 147° (massimo 154°). Parmi quindi scorgere dopo il raggiungimento dell'alto valore del 1935 anche un certo rilassamento che dura tutt'ora. Ho potuto infatti controllare le temperatura dei gas della Bocca Grande ancora nel 1949 (151°), nel 1950 (145°) e nel 1951 (146°) con una media di 147° quale è appunto quella del terzo intervallo.

Questo rilievo è interessante e starebbe a dimostrare che l'uniformità dell'attività fumarolica della Solfatara è solo apparente, giacchè l'esalazione rivela in un ristretto campo una oscillazione termica che sporadicamente può anche toccare valori inconsueti, senza per questo portare il vulcano a più alte fasi di attività fumarolica.

Come ho detto, l'esalazione di tutte le fumarole è solfidrico-carbonica. Ovunque il tenore in idrogeno solforato oscilla tra il 0,5 ed il 0,9 % (nelle mie analisi 0,6 circa), con il 0,3 - 0,8 % di azoto secondo i varî autori che si sono interessati di tale studio. Il resto è anidride carbonica. È da ricordare che il SALVATORE nel 1923 ed il Principe GINORI CONTI nel 1938 hanno riscontrato alla Bocca Grande pure piccole quantità di metano e di idrogeno e determinato il contenuto in vapor acqueo, trovando il primo un rapporto gas: vapore di 120 litri/ora ed il secondo 80,4.

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Per quanto la massa maggiore dei gas fuoriesca, come si è notato, attraverso la zona periferica di levante-mezzogiorno, parte dell'esalazione gassosa trova pure modo di sfuggire, molto suddivisa, attraverso il materiale che occlude il condotto vulcanico. Ciò è facilmente constatabile quando dopo qualche temporale la parte centrale del Piano Sterile si ricopre di uno spessore d'acqua, anche sottile, attraverso cui si vede gorgogliare il gas con estrema uniformità di diffusione e di intensità sull'intera superfice. Questi gas hanno modo di superare nel sottosuolo l'accumulo caotico dei frammenti rocciosi commisti al materiale terroso ed argilloso trascinatovi, che pure lo ricopre, e sul quale si raccolgono le acque meteoriche che ristagnano commiste a prodotti e residui dell'alterazione solfatarica, sopra il qual livello la copertura, che esteriormente costituisce il fondo craterico, ha nel suo spessore di pochi metri (4-5 al massimo) una struttura cavernosa, più accentuata nella zona meridionale del Piano Sterile, dove la volta diviene relativamente assai sottile.

Tra questo complesso di fattori hanno sede i pseudovulcanetti fangosi, fenomeno nettamente secondario della Solfatara. Tali manifestazioni infatti, come spiegò a suo tempo il Bassani, derivano semplicemente dal cedimento della sottile crosta del sottosuolo cavernoso, scalzata con le piogge dallo aumentato livello delle acque che, come si è detto, ristagnano a pochi metri di profondità e che vengono messe a nudo. Appare così una pozza d'acqua melmosa e nera, smossa dai gas in una finta ebollizione, che per il progressivo franamento delle pareti tende ad ingrandirsi. Se la melma è densa ed oppone resistenza, il gas si accumula in essa gonfiandola sovente anche in grosse bolle di fango lucente che poi, spezzandosi e simulando un'esplosione, spruzzano attorno brandelli di fango talvolta anche all'altezza di qualche metro, che poi ricadono nell'interno del bacino se non, ma di rado, attorno allo stesso orlo della buca. Nell'attuale « Fangaia » la temperatura del fango è di solito inferiore ai 100° e solo nel 1927 il Signore vi misurò 110°.

Questi pseudovulcanetti di fango hanno una lunga tradizione. Il Breislack pensa che l'esistenza di uno di essi sia accertata già nei tempi neroniani dal romano Petronio, quando questi scrisse che la Solfatara (Forum Vulcani) « est locus - Cocyta perfusus aqua ». Altrettanto doveva verificarsi nel 1343, quando il Petrarca visitando la Solfatara vide l'arida terra « ...cinerum globos et ferventes scatebras, aheni instar undantis, confuso murmure eructantem », frase che è assurdo, come ho notato altrove, riferire alla presunta eruzione del 1198, poichè sarebbe inconcepibile ritrovare dopo oltre un secolo e mezzo una lava ancora calda. Due fangaie (duas piscinas) descrive chiaramente mons. BURCHARDT che la vide nel 1494. Da quest'epoca fino alla fine del secolo XVIII le citazioni si ripetono sicure in numerosi scrittori i quali parlano di fosse, di bacini pieni di acque nere o più semplicemente di un'acqua nera che nasce nella Solfatara, nell'un caso o nell'altro bollente con gran impeto. La formazione dei pseudovulcanetti fangosi riprende nel 1874, si ripete nel 1898 ma con brevi durate, finchè nel 1913 ebbe origine la « Fangaia » ancora oggi esistente che, per nuovi sprofondamenti e per la raccolta del fango destinato ad applicazioni terapeutiche, da una buca di un metro di diametro è diventata un bacino ellittico di oltre 250 mq.

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Le radici bibliografiche della Solfatara sono sopratutto letterarie e solo STRABONE, come geografo, vi si inserisce con maggiore aderenza al soggetto. La fenomenologia mancò però sempre di quella grandiosità per cui gli altri vulcani della penisola sono rimasti così legati alle concezioni mitiche della antichità. Il luogo situato sull'amenissimo golfo di Baia e di Pozzuoli, così caro ai Romani, era da questi ben conosciuto ed assai vivo doveva apparire il contrasto tra la ricchezza lussureggiante della campagna vicina e l'acre suo squallore. La desolazione della Solfatara è descritta da PETRONIO ARBITRO con un così vivo lirismo che all'immaginazione d'allora oggi nulla può essere tolto, perchè le stesse parole si adattano alle nostre impressioni, all'attuale realtà veramente assai simile a quella di venti secoli or sono. Si ritrovano oggi, tali e quali, il campo di solfo ed i vapori puzzolenti ricordati da STRABONE, nello stesso regno squallido e mortale dove PETRONIO vide solo il Caos senza mai alcun segno di primavera. Non è certo sufficiente questa concomitanza per affermare che la Solfatara sia stata sempre così, tuttavia non si hanno sufficienti motivi per dover pensare diversamente giacchè nella sua struttura essa non rivela una vita tormentata.

Da STRABONE all'ALCADINO, medico della corte sveva di Palermo sulla fine del secolo XIII, sono trascorsi dodici secoli durante i quali rimane del tutto ignoto quanto può essere accaduto alla Solfatara. L'ALCADINO esalta le proprietà medicamentose dei fumi sulfurei e con ciò è da pensare che in quel tempo la Solfatara fosse come appare oggi e come l'aveva descritta STRABONE. Durante questi ultimi otto secoli le cronache non registrano nulla di particolare, salvo l'apparire negli scritti del MAZZELLA e del CAPACCIO sulla fine del 1500 e sul principio del 1600 rispettivamente, ma senza alcuna altra testimonianza, l' improvvisa notizia di un'eruzione avvenuta nel 1198, cioè ben quattro secoli prima. La mancanza di fonti bibliografiche contemporanee o vicine all'avvenimento rende già per i più inaccettabile l'esistenza di quell'atto eruttivo. Aggiungo, a convalidare tale opinione, e forse a maggior ragione, la mancanza di corrispondenti alterazioni morfologiche al cratere della Solfatara. Si può al più pensare ad una straordinaria maggiore attività fumarolica, che in qualche sua tradizione orale si è col tempo abbinata ad altra di più disastrosi terremoti, sicuramente avvenuti.

Un altro punto che ha dato luogo a false interpretazioni è quello relativo all'esistenza di un lago in corrispondenza dell'attuale « Piano Sterile », che in passato di tale lago sarebbe stato il fondo. Le molte stampe note, delle quali qui qualcuna è riprodotta, non danno affatto, come sovente si ripete, testimonianza di ciò, di cui neppure parlano esplicitamente gli autori che in passato si sono interessati della Solfatara. Le stampe riportano solo i vecchi e noti pseudovulcanetti fangosi ed anche gli autori discorrono solamente di quest'ultimi, come di cosa assai meravigliosa e null'altro.

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Nel complesso, la Solfatara induce a pensare con altissima probabilità ad una sua lunga quiescenza, così lunga e così pure caratteristica da far sì che GIUSEPPE MERCALLI abbia potuto chiamare « solfatarici » quei periodi che i vulcani attraversano in pressochè simili forme per tempi più o meno brevi.

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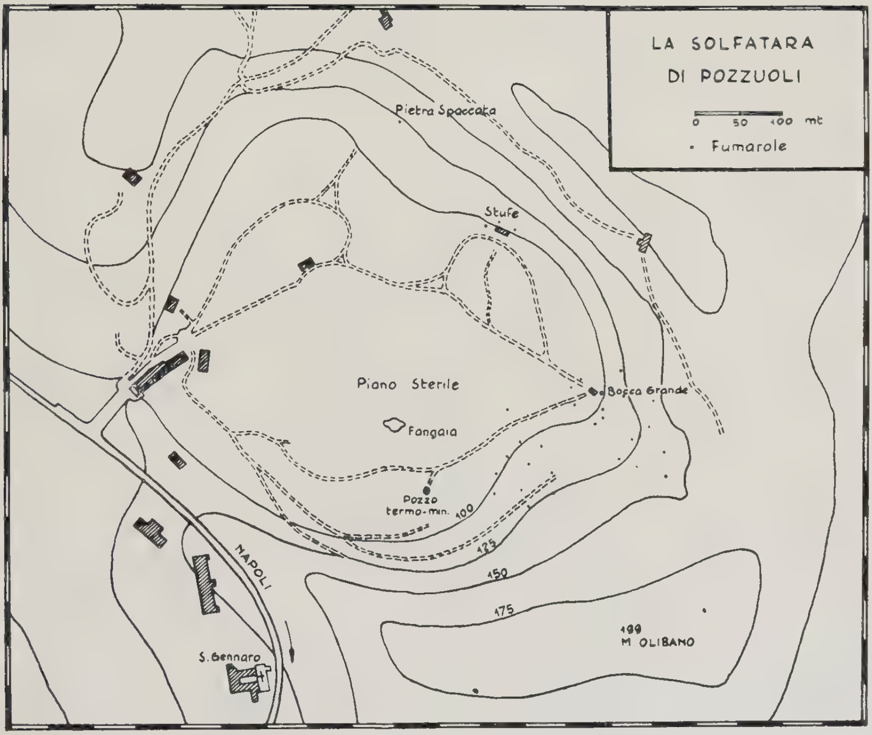
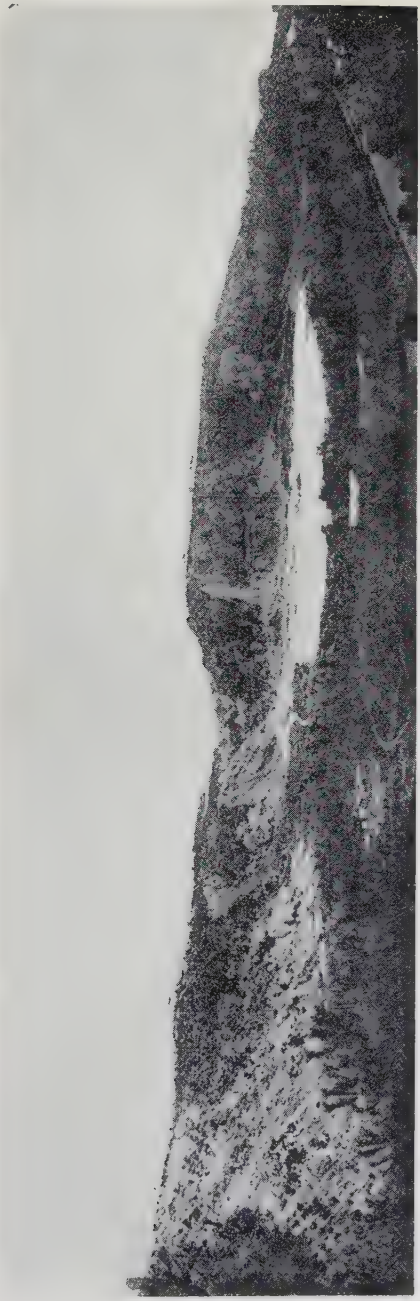
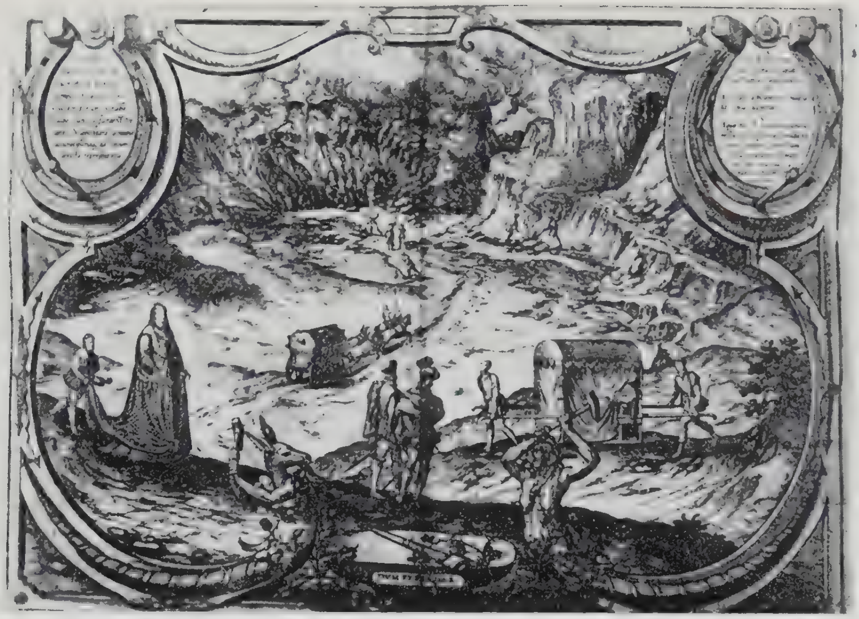


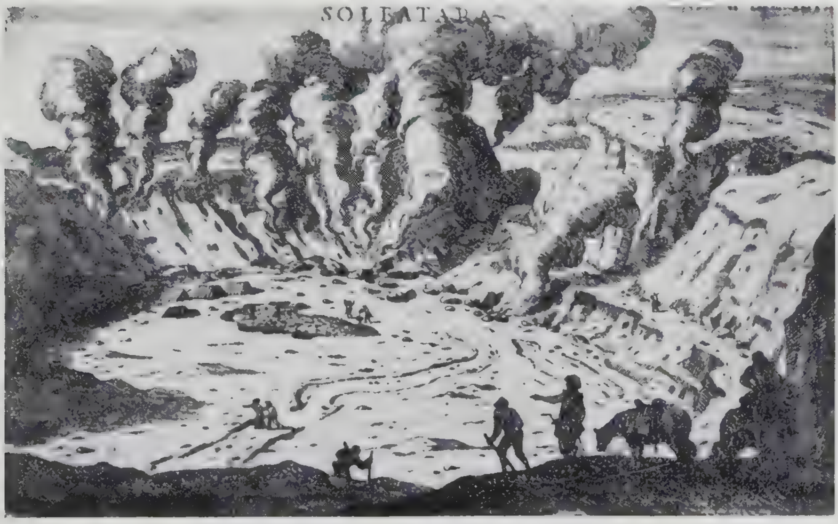
1. - La Solfatara di Pozzuoli.



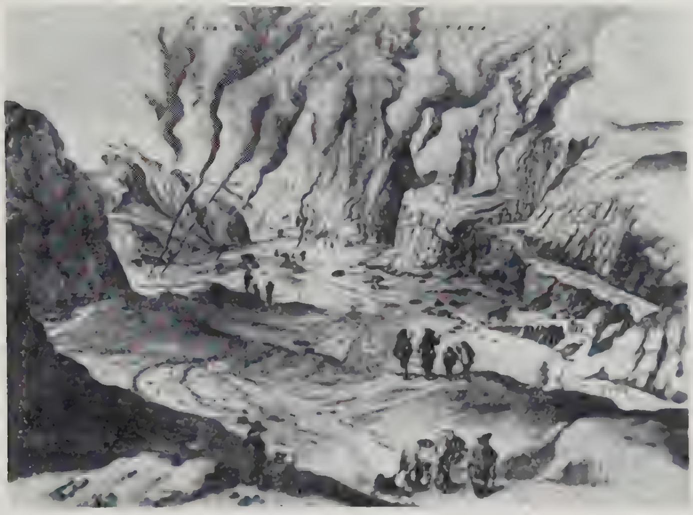
2. - La Solfatara vista da settentrione.



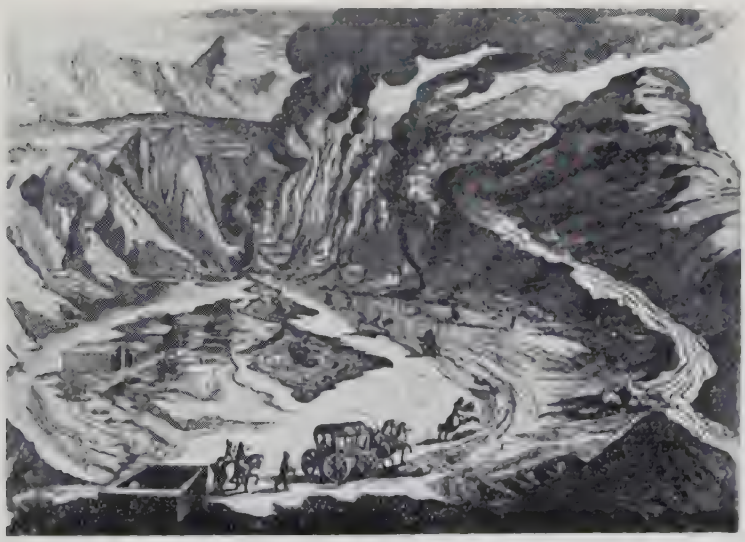
3. - Houfragel Giorgio - Civitatis Orbis Terrarum.
(Braun et Hogenberg, 1576-1618)



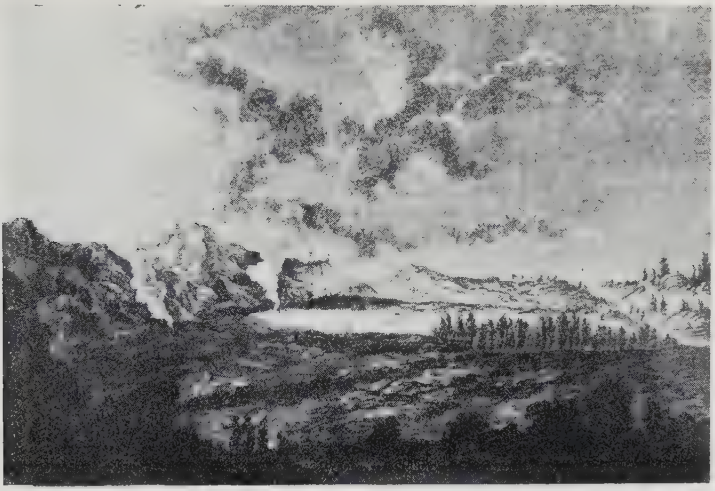
4. - Anonimo - Histoire Naturelle.
(Stampa di Bartolomeo Narici, fine sec. XVII)



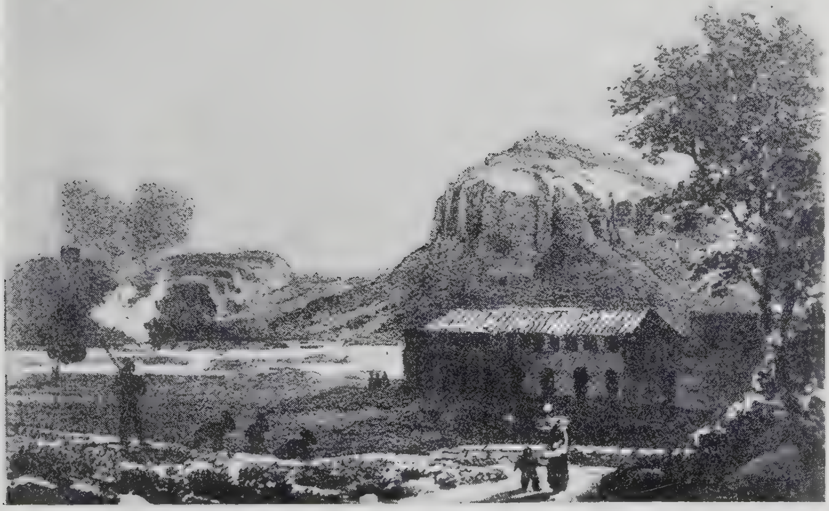
5. - Pierre Mortier - Forum Vulcani, *vulgo* Solfatara.
(Amsterdam 1650)



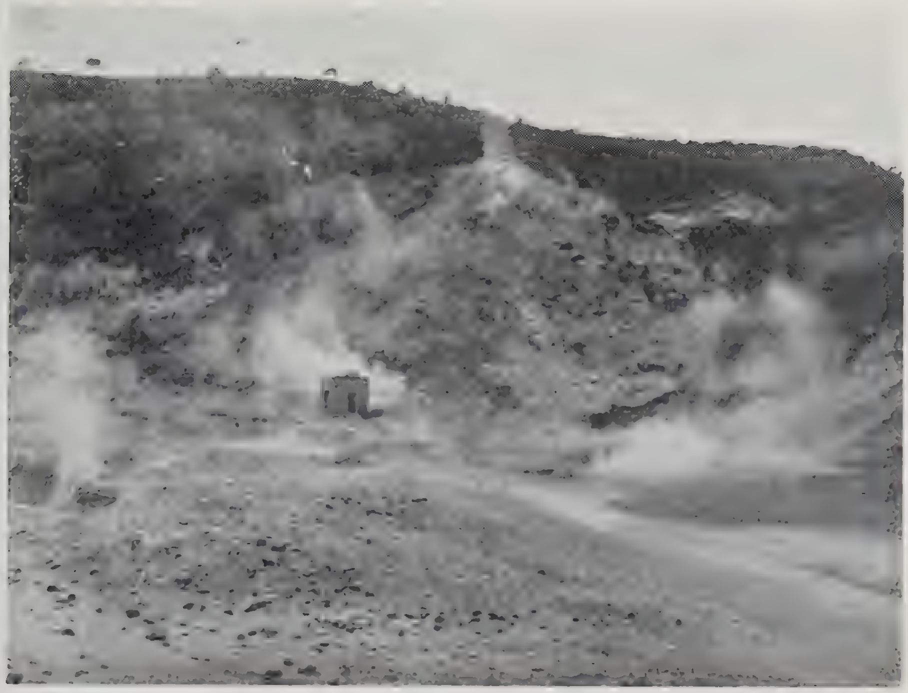
6. - Capaccio G. C. - La vera antichità di Pozzuoli.
(Napoli 1607)



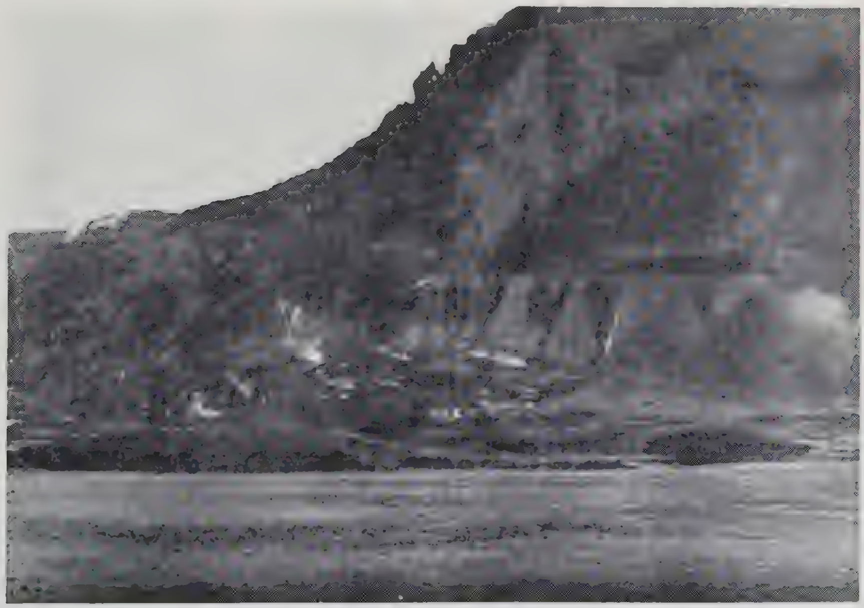
7. - Morghen F. - Le antichità di Pozzuoli, Baia e Cuma.
(Napoli, 1769)



8. - Liberatore R. - La Solfatara di Pozzuoli.
(Napoli 1838-1840)

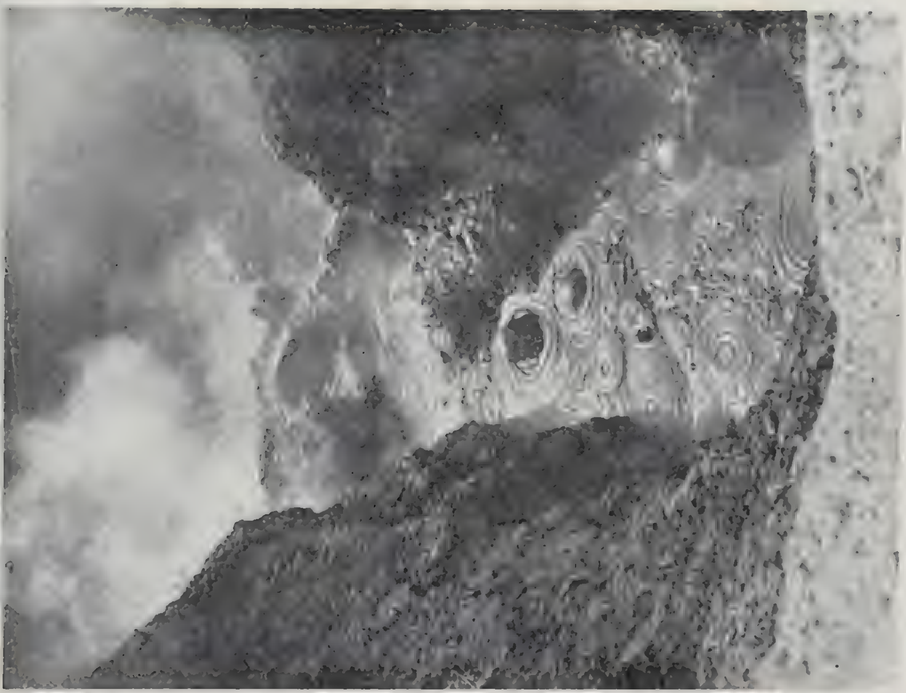


9. - Le fumarole del gruppo della Bocca Grande



10. - La « Piccola Solfatara ».

11. - La Fumarola della Bocca Grande.



12. - Nella « Fangaia ».

13. - La « Fangaia » ed il « Piano Sterile ».

14. - Nella « Fangaia ».

LUDOVICO SICARDI

Dell'esalazione solfidrico - solforosa nella attuale fase solfatarica dell'attività dell'isola di Vulcano e di alcune questioni ad essa inerenti

(Con 6 tavole)

Delle sette isole dell'arcipelago eolico, tutte di natura interamente vulcanica, due sole, Stromboli e Vulcano, si presentano in condizioni di perenne attività sia pure soggetta a quelle variazioni comuni a tutti i centri vulcanici. Nel triplice irraggiamento eolico le due isole si trovano in posizioni opposte sulle due radiali settentrionale e meridionale, delle quali esse occupano i rispettivi estremi. Anche la forma delle manifestazioni dell'attività, normale e parossismica, è opposta in dipendenza della diversità dei due magmi, di natura acida quello di Vulcano, basica per Stromboli. Da ciò tutta una conseguente fenomenologia, che le tradizioni e le cronache testimoniano attraverso oltre due millenni.

La struttura di Vulcano, l'isola che esclusivamente ci interessa in questa nota, è piuttosto complessa. Conosciute sono le vicende del vulcanismo locale le cui manifestazioni, salvo la formazione di Vulcanello nei primi secoli dell'era volgare, sono nell'epoca storica oramai concentrate sul Gran Cono o Monte della Fossa. Non entriamo in maggiori dettagli già sviluppati in altro lavoro e ricordiamo solo che l'ultimo periodo eruttivo, a carattere del tutto esplosivo, si ebbe dal 1888 al 1890. Cessata questa eruzione, l'attività si ridusse a manifestazioni fumaroliche nell'interno del cratere e sull'alto delle pendici di NW del Gran Cono nella cosiddetta batteria esterna di fumarole costituite da due nuclei segnati con altrettante crocette sotto q. 250 nella cartina della tav. 1.

Nel 1898 l'Arcidiacono registra una maggiore attività fumarolica, ma entro il cratere non pare che vi fossero temperature superiori ai 100°. Nel 1913 il De Fiore, che visita e descrive dettagliatamente il vulcano, riconosce alcuni gruppi fumarolici entro il cratere tra i quali la temperatura massima era di 110°. Solo nella batteria esterna, e precisamente nel nucleo a levante, i gas esalavano a 112°. Siamo agl'inizi di un intenso ciclo dell'attività fumarolica di Vulcano, ciclo non ancora conclusosi e che non è possibile prevedere se debba sfociare in una forma parossismica di attività esplosiva o nel ritorno ad un più calmo sviluppo dell'esalazione gassosa.

Nel 1916 il De Fiore trova uno spiccatissimo risveglio dell'attività fumarolica, con la formazione di una frattura radiale a cavallo dell'orlo craterico settentrionale in direzione NS con una temperatura massima dei gas di 352° ed un'altra allungata orizzontalmente da est ad ovest sulla parete craterica interna e sotto la precedente, alla quale quindi risultava perpendicolare, con un maggior massimo: 416°. Tra le altre fumarole non si superavano i 100° eccetto nel nucleo più settentrionale della batteria esterna, con 140°. Nella cartina della tav. 1 i gruppi fumarolici delle due fratture sono schematicamente segnati con due crocette, rispettivamente a nord ed a sud della linea tratteggiata indicante la quota 250 nell'interno della Fossa.

Questa tendenza dell'attività fumarolica ad investire il settore di NNW della zona terminale del Gran Cono si manifestò anche oltre il Monte, giacchè un nuovo gruppo di fumarole a 100°, però esclusivamente idrocarboniche, si era formato sotto il dirupo di Lentia (probabilmente nel 1915), mentre tra i Faraglioni del Porto di Levante l'antichissima sorgente dell'« Acqua Calda » ed una diffusa esalazione permeante il terreno si completano con un discreto gruppo di fumarole a 100° e idrosolfidricocarboniche. Non si può tralasciare di ricordare che più a nord è Vulcanello, il gruppetto già ricordato dei giovani e spenti crateri con il solo residuo di una tenuissima appena tiepida esalazione nella più recente formazione. Tutto questo sta a marcare l'importanza che nel nostro vulcano ha la direttrice NS, che è pure la massima dimensione dell'isola.

Le maggiori manifestazioni, termicamente e chimicamente più imponenti, sono sempre state in questi ultimi decenni quelle della Fossa. Il valore più alto riscontrato tra le temperature massime dei maggiori gruppi, cioè sulle due fratture e la batteria esterna, costituisce l'indice corrispondente più significativo dell'ampiezza dell'attività fumarolica craterica. Nell'estate del 1921 il Malladra e nell'autunno ancora il De Fiore riconoscono nuovi incrementi termici che io confermo durante l'inverno-primavera del 1922 e di nuovo nello stesso periodo del 1923. Nell'ottobre del 1924 il De Fiore misura 615° sulla frattura interna. È questa la massima registrazione termica fatta a Vulcano. L'Imbò nel 1930 e nel 1932 trova 364° e 384°, verso cioè quei 465° che saranno misurati nel 1933 da Dessau e Bernauer. Successivamente non dispongo che delle mie osservazioni del 1937 (T° max 170°) e del 1951 (T° max 246°).

Il diagramma della tav. 2 riporta l'andamento termico dell'esalazione dal 1913 al 1951. Esso è costruito prendendo in considerazione i massimi termici annuali risultanti dai dati raccolti alla Fossa di Vulcano dai vari Autori sopraricordati (v. Bibliografia). Per quanto l'andamento del diagramma sia abbastanza significativo, tuttavia è spiacevole la limitazione di due soli segmenti a linea piena mancando l'assicurazione, anche approssimata, che il massimo termico del '24 non sia stato superato (in ogni caso però non eccessivamente), come pure che la successiva discesa termica non abbia toccato un valore ancor più basso. Altrettanto deve dirsi per l'intervallo 1937-51, non potendosi legare senz'altro le due letture, essendo arbitrario escludere un diverso andamento intermedio per oltre un decennio.

In un rapido, schematico disegno dell'attività fumarolica al cratere del Gran Cono di Vulcano dal 1890 al 1951 si può dunque concludere riconoscendo con sicurezza un primo periodo caratterizzato da un lento, progressivo incremento della termicità e della distribuzione fumarolica con il raggiungimento di una temperatura di 110° - 112° nei diversi gruppi di fumarole. Segue un secondo tempo, fino a poco dopo il 1924 con ogni probabilità, durante il quale la temperatura dei gas si accentua fino al raggiungimento di un massimo misurato di 615°. All'incremento termico che investe il settore settentrionale del cratere (nelle altre parti la temperatura dei gas si mantiene sui 100°) fa riscontro una progressiva e sempre più distesa fratturazione del terreno, nonchè la formazione di nuove zone fumaroliche a N e a NW del Gran Cono. A questa veramente alta termicità segue una caduta riconosciuta nel 1930 (364°), che può però essere stata preceduta da valori anche più bassi. Comunque si è avuto un notevole abbassamento termico (con la scomparsa delle fumarole di Lentia e l'affievolimento di quelle del Porto di Levante) cui segue un nuovo periodo di ascesa controllato ancora nel 1932 (388°) e nel 1933 (465°), che indubbiamente non ha raggiunto l'altezza della punta massima precedente e che è stato seguito egualmente da una nuova fase di discesa come appare nel 1937 (170°). Il massimo valore termico misurato nel 1951 (246°) rivela l'esistenza di una terza punta massima o l'avviamento ad essa, senza però, come ho già detto, sia purtroppo possibile una migliore definizione. Si può solo dire con sicurezza che tale andamento è accompagnato da un nuovo allargamento della zona di fumarolizzazione sempre nel medesimo settore craterico, con la formazione di nuove fessure nello stesso sistema delle fratture già precedentemente sviluppatesi. Ne consegue una maggiore ramificazione della parte esterna della frattura radiale a cavallo dell'orlo craterico, mentre la frattura sulla pendice interna si amplifica trasformandosi in un'estesa zona di ampia fratturazione. Tutto ciò appare assai evidente in un attento confronto delle tav. IV, V, VI.

Il deciso incremento termico della prima fase è stato accompagnato da un eccezionale fenomeno: l'emissione di zolfo liquido. Il fatto si è verificato quattro volte e sempre nella zona compresa tra i due gruppi della batteria fumarolica esterna sull'alto del Gran Cono, poco prima del 1916, nel 1918, nel 1922 e nel 1923. Mentre nel 1916 si è notata la semplice formazione di una stalattite di zolfo, successivamente sono sgorgate ben 400, 100 e 300 quintali di zolfo rispettivamente. Senza dubbio l'incremento termico con il suo avanzarsi ha portato alla rifusione di zolfo già presente e depositatosi negli anfratti di quella zona della parte più alta del monte compresa sempre nel settore di NW, pervasa sopratutto dalla più lenta, periferica diffusione fumarolica. Questa per il suo carattere solfidrico-solforoso si prestava nel suo più facile raffreddamento alla formazione di zolfo, a sua volta facile a rifondere con lo svilupparsi dell'incremento termico dell'esalazione ed ovviamente di tutto il terreno compreso tra i maggiori centri fumarolici.

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Se lo studio termico delle fumarole crateriche per essere stato frequentemente ripetuto permette di delineare con sufficiente chiarezza da questo lato l'attività fumarolica quasi di un quarantennio, lo studio chimico, al quale io mi sono particolarmente dedicato, è limitato a tre soli momenti: 1923-1937-1951, gli anni cioè nei quali appositamente mi recai a Vulcano, giacchè la mia prima permanenza del 1922 aveva altri scopi. Tali limitazioni non pregiudicano tuttavia l'interesse che scaturisce dai risultati raggiunti.

Durante la lunga permanenza del 1923 potei studiare ampiamente la distribuzione fumarolica, le caratteristiche termiche e chimiche dei gas, la radioattività ed il contenuto in vapor acqueo degli stessi. Di tale studio vi è un'ampia relazione in questo stesso Bollettino (vol. VII della 2ª serie). Nel '37 invece e nel '51 non mi trattenni che pochi giorni e dovetti concentrare le notazioni termiche e la raccolta dei gas in una sola giornata passata al cratere e per di più in condizioni meteorologiche sfavorevoli, specie nel 1951. Comunque anche i dati raccolti nel '37 e nel '51 (quest'ultimi ancora inediti) non mancano di interesse collegati a quelli del '23 e qui, con una presentazione più sintetica delle caratteristiche chimiche dell'esalazione craterica, mi è possibile qualche considerazione con una maggiore estensione di quanto già abbia fatto precedentemente.

Il fatto più saliente riconosciuto nello studio dell'esalazione delle fumarole crateriche di Vulcano, per il riflesso che ne deriva a più ampie generali conoscenze, è dato dalla coesistenza in alte proporzioni dell'idrogeno solforato e dell'anidride solforosa e poi dalla idricità dei gas ad alta temperatura. Già nell'inverno 1922 avevo potuto constatare la presenza dei due gas in una stessa fumarola, per il fatto che con la raccolta in tubi di vetro per aspirazione mi trovavo poi ad avere solo anidride solforosa, quando anche l'annerimento delle cartine all'acetato di piombo attestavano senza ombra di dubbio la presenza dell'idrogeno solforato entro il medesimo orifizio fumarolico. Da tale constatazione scaturì il mio particolare interesse allo studio chimico dell'esalazione di Vulcano. In conseguenza dovetti preoccuparmi di realizzare uno speciale sistema di captazione dei gas fumarolici con conseguenti idonei criteri analitici. Le conclusioni cui giunsi nel '22 e nel '23 furono poi modificate, giacchè, se allora potevo disporre di un attrezzato laboratorio in situ, ciò non mi fu possibile nel '37 e nel '51. Di tali lavori do ogni ragguaglio in altre mie due note, la seconda delle quali, più completa e definitiva, è pubblicata nel vol. XVII di questo Bollettino.

Nella tabella sono associati valori termici e composizioni gassose quali mi fu possibile stabilire nelle tre diverse epoche in differenti condizioni di intensità dell'attività fumarolica craterica.

Gas	1923			1937		1951	
	480°	237°	104°	170°	138°	210°	187°
	1	2	3	4	5	6	7
HCl	1,7	1,5	—	0,2	0,2	0,6	0,5
SO_2	21,2	18,9	18,2	6,3	3,0	4,5	3,5
H_2S	20,0	17,3	17,0	5,5	2,2	3,9	2,9
CO_2	55,2	59,6	62,4	86,0	92,3	88,9	91,3
N	1,9	2,7	2,4	2,0	2,3	2,1	1,8

Le analisi 1 - 4 - 5 - 6 si riferiscono a massimi termici riscontrati sulla grande frattura radiale N-S che, ricordo ancora, taglia l'orlo settentrionale del cratere. Le altre sono state fatte su gas raccolti, dove la termicità era massima, tra gruppi di fumarole situati poco distanti dall'estremo nord dell'anzidetta frattura e sulla stessa direzione di quest'ultima. Si tratta quindi di un complesso di sette analisi effettuate su gas a temperatura superiore ai 100°, in posizioni legate da pari condizioni genetiche, topograficamente omogenee e quindi assai significative nel loro insieme e nei massimi dei propri valori temporalmente o topograficamente considerati.

Dall'esame dei dati analitici emergono immediatamente alcuni fatti:

1° La coesistenza dell'idrogeno solforato e dell'anidride solforosa. Questa constatazione fissa una caratteristica generale di tutta l'esalazione fumarolica di Vulcano a temperatura superiore ai 100°, che è quella qui considerata. Noto solo incidentalmente che al disotto di questa temperatura tale coesistenza è rara. La contemporanea presenza dei due gas in una stessa fumarola in percentuali così elevate non era ammessa in addietro (MERCALLI: *I Vulcani attivi della Terra,* Milano 1907, pag. 218), essendo nota la reazione delle due sostanze per dare acqua e zolfo. Non si è badato che ciò accade in condizioni ordinarie di temperatura, particolarmente con gas umidi e non a temperature più alte, quando i gas non si trovano in presenza di vapor acqueo condensato, nelle cui goccioline la reazione ha il suo più favorevole ambiente.

2° La impossibilità di stabilire un rapporto quantitativo tra temperatura e composizione gassosa. Nel 1923, quando a Vulcano la attività fumarolica era già assai vicina al suo massimo, la percentuale dei due gas solforosi a 104° era più alta di quanto si è riscontrato nel 1937 e nel 1951 a temperatura maggiore ma in un ambiente di minore attività, considerando giustamente questa in funzione del massimo termico corrispondente.

3° Pratica eguaglianza delle percentuali di anidride solforosa ed acido solfidrico nell'esalazione. Indipendentemente dalla temperatura e dalle condizioni generali dell'attività fumarolica, la percentuale dell'anidride solforosa è sempre costantemente superiore a quella dell'idrogeno solforato. Si tratta però sempre di una differenza non elevata per cui i valori sembrano tendere ad una certa eguaglianza.

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La coesistenza dell'anidride solforosa e dell'idrogeno solforato e la vicinanza delle due percentuali rivelano ed accentuano un parallelismo che non può essere privo di significato, tanto più che ciò è indipendente dalla grandezza di siffatto contenuto nell'esalazione. Una interpretazione di questi fatti può trovare un appoggio nella constatazione già fatta da Adolfo Brun, il vulcanologo svizzero tenace propugnatore dell'anidrità dei magmi, sulla presenza del protocloruro di solfo nei magmi. (A. Brun: *Recherches sur l'exhalation volcanique*, Ginevra 1911, pag. 168). Questa sostanza è infatti scomposta dall'acqua, che a Vulcano ho trovato abbondantemente presente nell'esalazione craterica anche ad alta temperatura ed in ragione di un massimo di gr. 22 per litro di gas anidro. Nella reazione $S_2Cl_2 + 2H_2O = H_2S + SO_2 + 2HCl$ si giunge ad una produzione di volumi eguali di idrogeno solforato e anidride solforosa. Però si ha pure formazione di una notevole quantità di acido cloridrico, che le mie analisi non rivelano limitandosi esse a mostrare una certa proporzionalità tra contenuto in acido cloridrico e temperatura. Il fatto tuttavia che nelle fasi parossismiche dell'attività vulcanica abbondino acido cloridrico e cloruri alcalini fa pensare che l'acido possa restare assorbito nel magma, fino a che non è realizzato l'effetto parossismico.

Il problema così posto viene immediatamente a collegarsi con la questione dell'anidrità del magma dei vulcani. Se ne potrebbe trarre un argomento favorevole per la presenza dell'acqua, giacchè la scissione del protocloruro di solfo non potrebbe avvenire che nelle zone magmatiche profonde, per rendere possibile il riassorbimento temporaneo dell'acido cloridrico nel magma stesso. L'acqua riconosciuta presente a Vulcano mi sembra di origine magmatica, sia perchè i dati pluviometrici locali a stento si accordano, come ho discusso altrove, con la quantità di acqua presumibilmente emessa dal vulcano, sia perchè, in tesi generale, non mi riesce di poter ammettere che l'acqua di una falda acquifera di circolazione più o meno profonda riesca a giungere in contatto di un magma, restandone assorbita. Una tale possibilità è inammissibile, giacchè qualsiasi via portante al magma rimane preclusa sotto l'azione della tensione dei gas che l'esistenza di tali vie rende automaticamente presenti, senza contare che la zona limite dell'azione repulsiva esercitata dai gas è ancora avvolta da una fascia di termicità, che le acque devono inevitabilmente incontrare ed alla cui azione evaporante non possono sottrarsi.

Si può quindi supporre solo perifericamente il miscelamento di gas magmatici con vapor acqueo, dando luogo ad una circolazione nettamente idrotermale. L' unica possibilità alquanto diversa cui mi sembra di poter pensare, perchè del vapor acqueo riesca a lambire il magma, potrebbe presentarsi, e si tratta di una situazione eccezionale, laddove sul bacino, o su analoghe posizioni magmatiche, si determinano delle depressioni e quindi il moto ascensionale dell'emulsione magmatica, come tipicamente accade nel condotto di un vulcano. In tal caso è verosimile che acqua sotterranea possa essere « aspirata » attraverso la porosità del terreno da una colonna gassosa ascendente. Una siffatta condizione è ammissibile, senza però che debba per questo restare esclusa un'acqua magmatica nel campo delle supposizioni fatte precedentemente per legare la reale coesistenza dei due gas solforosi con la ipotetica derivazione di essi dal procloruro di solfo.

Questi quesiti appariranno, e giustamente, troppo distanti dalle risultanze delle mie ricerche analitiche. Si tratta comunque di rapporti sui quali non ritengo di essermi soffermato del tutto inutilmente con la presentazione dei dati di fatto raccolti sul terreno. A prescindere da tali rapporti, è assai difficile ritenere che la coesistenza dei due gas sia solo specifica di Vulcano sicchè, generalizzato il fatto, ne resta in ogni caso amplificata l'incidenza nel quadro di tutta la fenomenologia vulcanica. E questa è la più precisa e più sicura conclusione.

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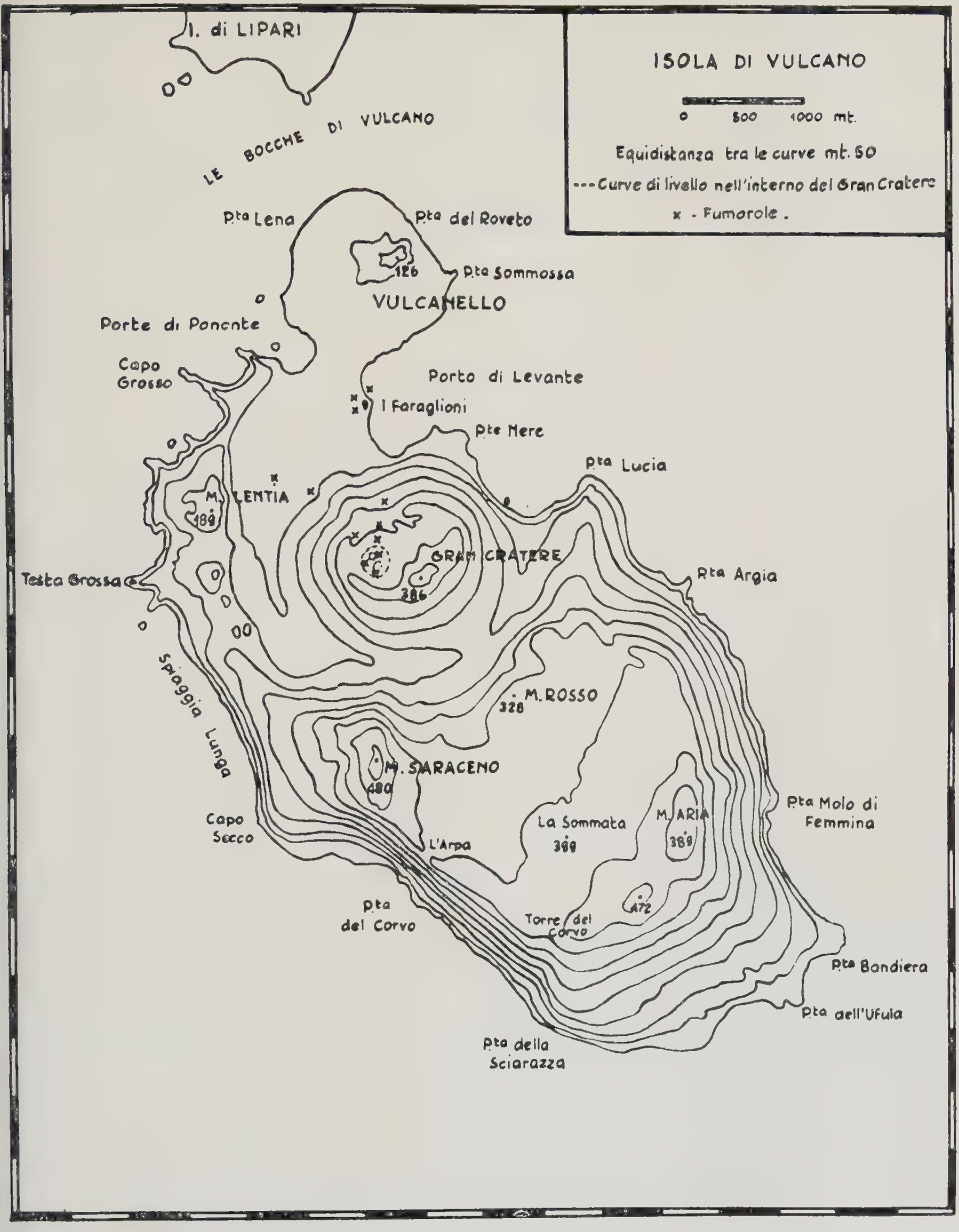
N. B. - Nel volume « *Vulcano* » del Prof. O. De Fiore è raccolta una bibliografia vulcanologica dell'isola aggiornata al 1922. Ulteriori citazioni trovansi nel primo dei miei lavori.

TAVOLE

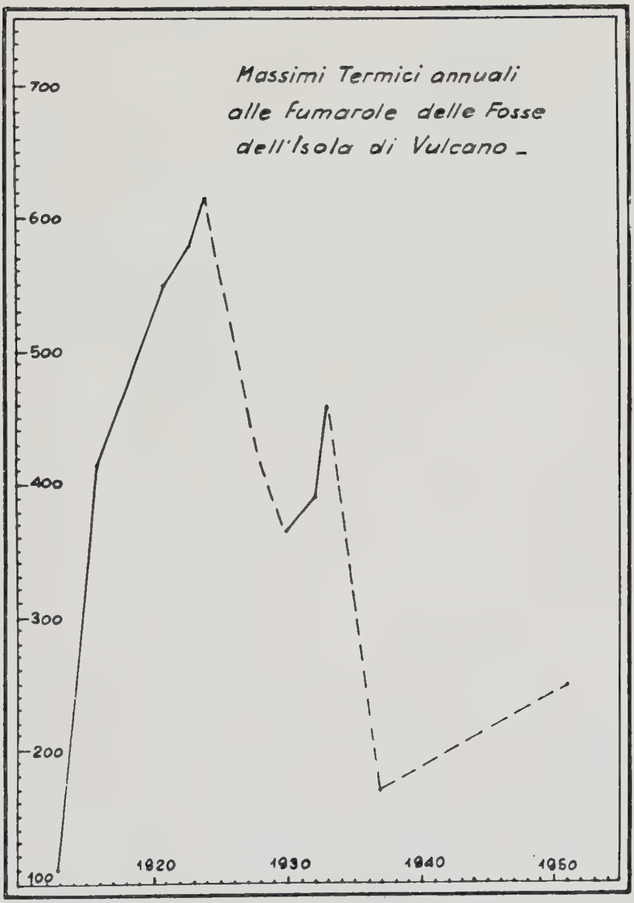
Tav. I

DOVICO SICARDI — *Dell'esalazione solfidrico-solforosa nell'attuale fase solfatarica dell'attività dell'isola di Vulcano e di alcune questioni ad essa inerenti.*



1 - L'Isola di Vulcano.
(Dalle carte dell'I. G. M.)

Tav. II

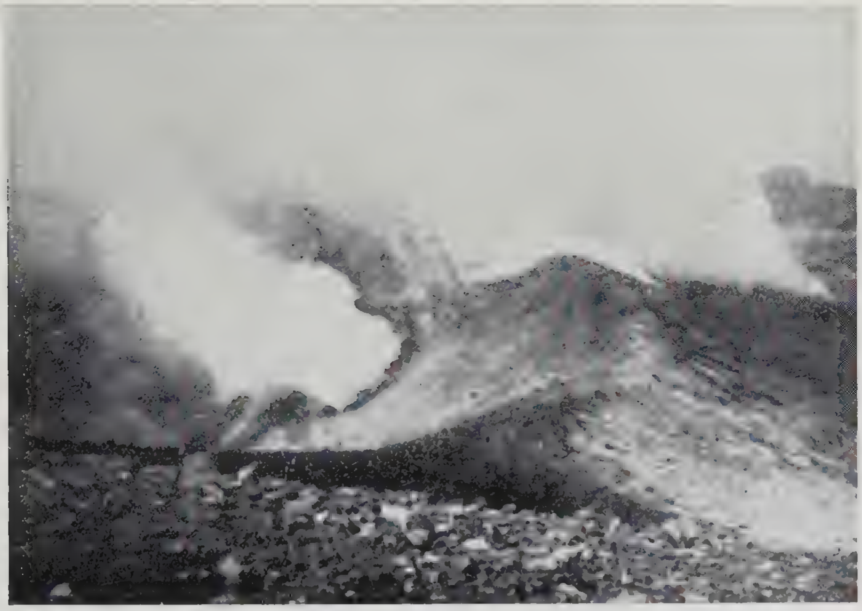


2 - Diagramma sui massimi termici misurati all'esalazione fumarolica craterica dal 1913 al 1951.

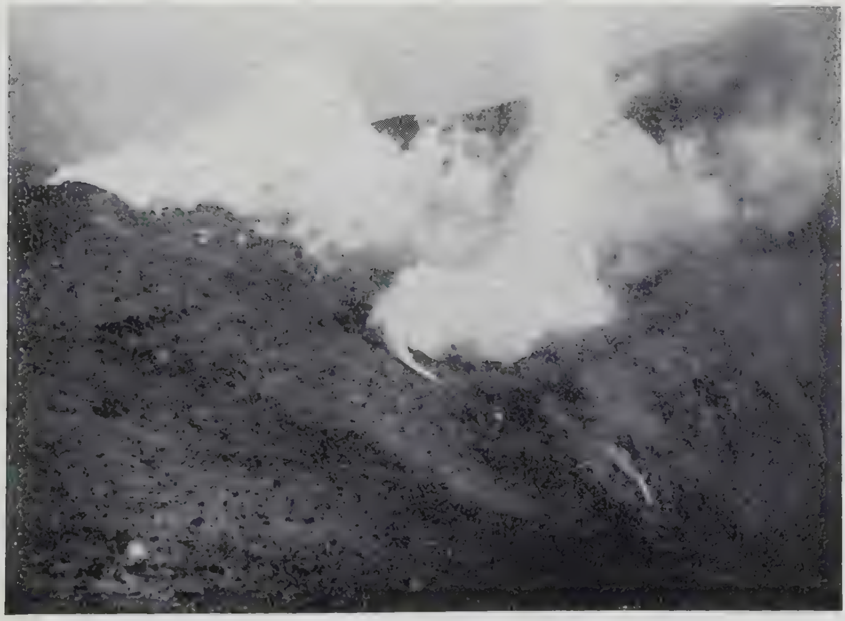
3 - Il Gran Cono con le fumarole esterne ed il cratere avventizio della « Forgia Vecchia ».

4 - Vulcanello dalla cima del Gran Cono.

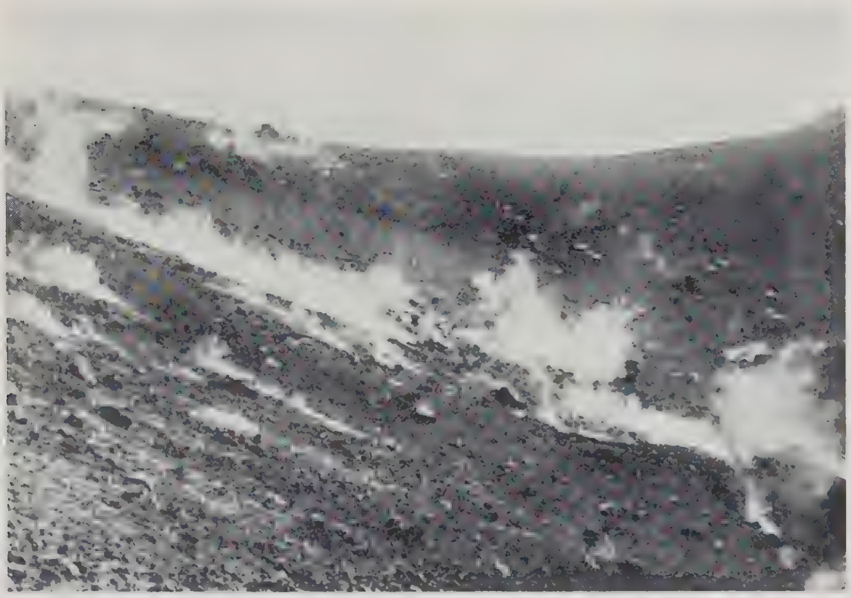
Ludovico Sicardi — *Dell'esalazione solfidrico-solforosa nell'attuale fase solfatarica dell'attività dell'isola di Vulcano e di alcune questioni ad essa inerenti.*



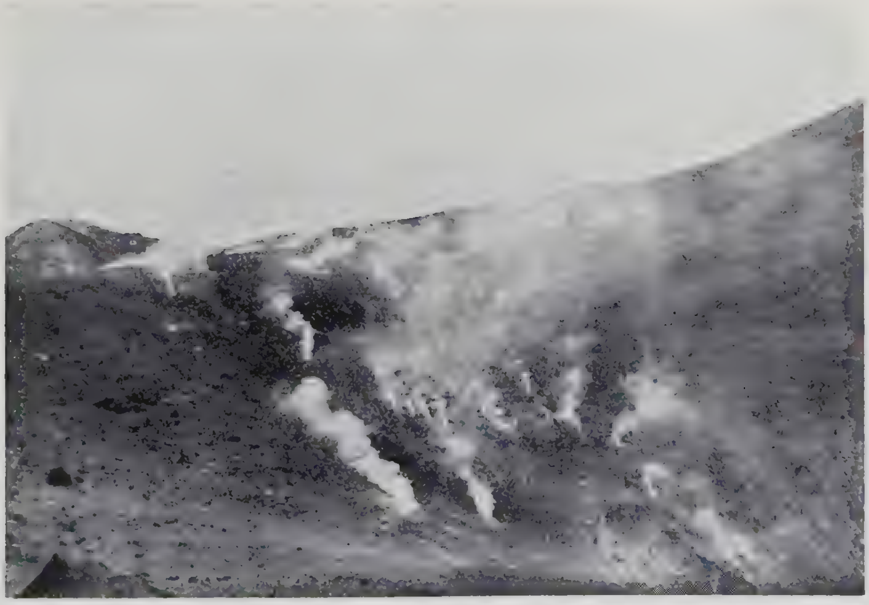
5 - Le fumarole sulle fratture EW e NS (nell'interno e sull'orlo della Fossa) e in fondo la batteria esterna sotto q. 250 (primavera del 1921).



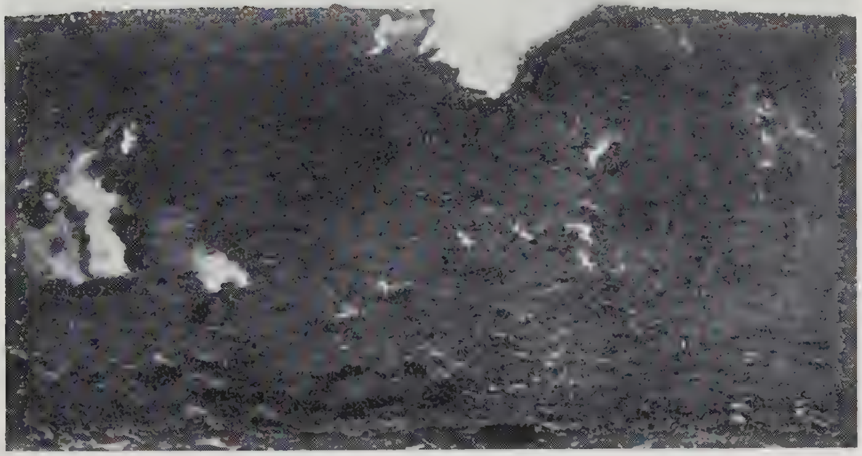
6 - Le fumarole sulle due fratture della Fossa nella primavera del 1922.



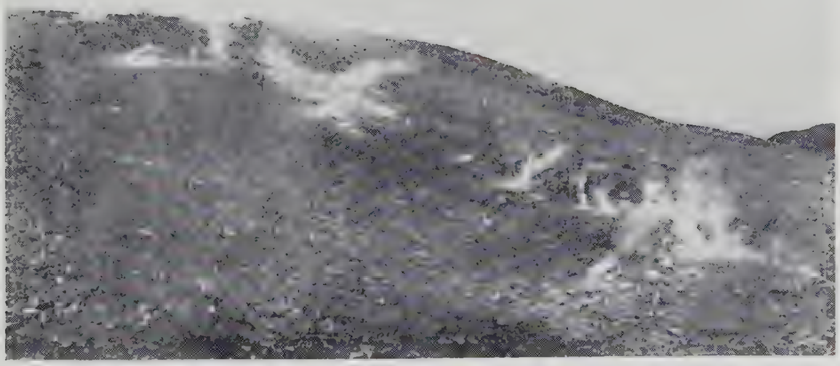
7 - La frattura EW nel 1937.



8 - Le fumarole delle due fratture della Fossa nel 1951.



9 - Il ramo esterno della frattura NS nella primavera del 1922.



10 - Il ramo esterno della frattura NS nell'estate del 1951.

GORDON A. MACDONALD [1]) and ARTURO ALCARAZ [2])

Nuées ardentes of the 1948-1953 eruption of Hibok-Hibok *)

(With 10 figs.)

Introduction

With the first description of nuées ardentes, during the 1902 eruption of Mont Pelée and the Soufrière of St. Vincent, controversy immediately arose concerning the nature of the explosions that initiated them. LACROIX (1904, 1908) believed that many resulted from blasts directed laterally at low angles; whereas ANDERSON and FLETT (1903) believed they resulted entirely from vertically directed explosions, gravity alone driving them down slope. There appears never to have been any doubt that nuées ardentes can result from the voluminous fall of vertically projected debris onto the outer slopes of the volcano, as concluded by ANDERSON and FLETT at St. Vincent in 1902, and by many investigators since then; but their formation by explosions directed at low angles continued to be a matter of debate. The uncertainty has been largely removed by PERRET's (1935) observations at Mont Pelée in 1929, and MACGREGOR's (1952, pp. 50-62) reanalysis of the observations on the 1902 eruption.

There is little doubt that low angle blasts from the sides of domes do initiate some nuées ardentes. It seems worthwhile, however, to record some additional evidence for their existence during the recent eruption of Hibok-Hibok volcano, in the Philippines, as well as some data concerning the composition

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*) Published with the approval of the Director, U. S. Geological Survey.

the earthquakes most persons had left the area around the base of the mountain, and the only casualities were two persons caught at the edge of the affected area who suffered second- and third-degree burns, but survived.

Other weaker blasts occurred during the rest of 1948, 1949, and 1950. On September 15, 1950, another blast similar to that of September 1, 1948, devastated the Ilihan area on the northern slope of the mountain, and claimed several victims. This is believed to have been a « nuée ardente d'avalanche » (Alcaraz, Abad, and Quema, 1952, pt. 2, p. 1), probably of the « Pelée directed lateral type » of MacGregor (1952, table 2), as also were most of the other nuées ardentes of 1948-1950. It is noteworthy that they were not only smaller, but of lower temperature than the great blasts of December 1951, described later. Neither clothing of victims nor houses within the devastated areas caught fire.

Following the explosion of September 1, 1948, lava extrusion began on the northeast side of the mountain. The vent of the flow was below the crater lip, probably on a northeast-trending lateral fissure. Extrusion continued into 1949, and formed a thick flow of block lava known as the Kanangkaan flow (fig. 1). Another smaller flow (the Itum flow) was formed a little farther south during the interval from June 1949 to September 1950; and a third (the Ilihan flow) formed on the north side of the mountain in late 1950 and 1951. Extrusion shifted back to the Itum area in December, 1951.

In May, 1949, a dome started to build in the crater northeast of the old domes, at approximately the site of the solfataras of 1897 and 1902, and the explosion of September 1, 1948. During the next two years it continued to grow slowly, until by late 1951 it was a prominent feature filling nearly all of the crateral depression and overlapping onto the northeast slope of the mountain. The dome continued active until early 1953, but since that time there has been no appreciable further growth, and crumbling of the dome has reduced its slopes essentially to stability. The last large avalanche resulting from collapse of part of the dome, occurred in May, 1953; and the last observed eruptive activity was a small ash explosion on

July 14 of that year (E. Omahoy, unpublished reports to the Commission on Volcanology).

The nuées ardentes of December, 1951

The most violent and destructive nuées ardentes took place in December, 1951. During the morning of December 4 a nuée ardente swept down the northeast side of the mountain into the outskirts of Mambajao, killing 500 persons. Trees were blown down and aligned along the course of the blast. Others left standing nearer the edge of the devastated area were charred on the side toward the volcano, but not on the side away from it. Houses were burned. Bodies of persons and animals were charred and mummufied. The force of the blast is attested by the fact that a coconut tree 25 centimeters in diameter was wrapped in the form of a U around a mango tree 5 kilometers from the source of the blast. Another, smaller blast occurred at 6:40 p. m. on the same day.

Before daylight on December 6 another similar cloud descended the mountainside, reaching nearly to the sea 1.5 kilometers west of Mambajao. In the pre-dawn darkness the entire segment from the summit of the mountain to the coast was aglow from the deposit of incandescent ash. The bright red incandescence indicates that the material had a temperature of at least 700° C. The deposits of both the December 4 and December 6 nuées ardentes remained unbearably hot beneath the surface for many days.

The nuées ardentes originated at the active dome at the summit of the mountain. At the northeastern foot of the mountain they encountered the slopes of Mt. Mambajao, and were deflected northward. Their major portions followed the valley of the stream crossed by the road 0.8 kilometer east of Baylao. The valley was too small to confine the cloud of December 4, which spread laterally both east and west of the valley (figs. 1 and 2). The cloud of December 6 was more nearly confined to the valley, but spilled over to the northwest north of Itum (fig. 2). The strong effect of topography in guiding the nuées ardentes clearly indicates the importance of gravity in their movement and their essential similarity to lava flows. Indeed, we regard a nuée ardente as essentially an unusually mobile auto-expansive lava flow.

Each nuée ardente consisted of a lower principal avalanche portion composed of a relatively dense emulsion of incandescent ash and gas bearing a suspended load of partly active and partly inert blocks of rock derived for the most part from the summit dome, overlain by a spectacular billowing and rapidly expanding, but relatively diffuse cloud of fine ash. The relatively dense lower avalanche portion produces the principal deposits of the nuées ardentes, though the great cloud above it also produces relatively thin deposits of fine ash that may extend over much larger areas than the deposit of the avalanche portion. The lower portion of the nuée ardente also is responsible for most of the serious damage, though for a variable distance beyond the edge of the avalanche portion the overlying cloud may be hot enough to kill animals and persons.

In the region northeast of Itum the deposits of the nuées ardentes filled the valley to an estimated depth of 100 meters (fig. 3).. The level of the top of the lower avalanche portion of the active nuée ardente was about 150 meters above the former valley bottom near Itum . Along the southeast side of the valley there are small discontinuous deposits and signs of scouring of the valley walls to that height. However, the surface of the principal permanent deposit in the valley bottom is about 50 meters below that highest level, partly because of compaction of the avalanche material as it lost its gas, but perhaps also partly owing to a recession of the flow during its later stages from an earlier flood stage of maximum depth. On the northwest side of the valley the nuée ardente of December 6 spilled over the Kanangkaan flow, leaving deposits on its surface about the same distance above the top of the principal valley-filling deposit as are the minor deposits along the side of the valley northeast of Itum.

Toward the coast the deposits become much thinner. One to two kilometers southwest of Mambajao the ash of the December 4 nuée ardente is only a few centimeters thick. The deposit of the December 6 nuée ardente at the road just east of Baylao averages about 60 centimeters thick. In the latter area trunks of standing coconut trees are charred to a height of about 5 meters above the ground.

The deposits in the upper part of the valley are unstratified, and consist of a heterogeneous assemblage of fragments of pumice grading into sand-size ash, containing breadcrust bombs and angular fragments of glassy banded dacite. The latter closely resemble the rock of the dome, and undoubtedly were derived from it. As far down stream as the road near Baylao blocks of dacite 5 meters across are fairly common, and some are as much as 10 meters across.

The material on the higher ground east of the valley, southwest of Mambajao, is entirely fine ash without bombs or large blocks, as might be expected if the denser lower portion of the nuée ardente was confined to the valley axis.

One large block, with dimensions originally about 10 by 8 by 5 meters, exploded after coming to rest on the surface of the December 6 deposit about 600 meters south of the road (2.5 kilometers from its source at the dome). The explosion caused a loud detonation heard by people nearby, and threw angular fragments of the block to a considerable distance with sufficient force to imbed some of them in coconut trees 20 meters away. The block was torn into three large fragments (fig. 4) and many smaller ones. The interior of the block was still plastic at the time of the explosion, and the surfaces of the large fragments formerly in contact are very rough and spinose where the plastic material was pulled apart. The explosion of this block clearly illustrates the active character of the material of the nuée ardente, which continues to evolve gas during the emplacement of the flow.

The early stages of the nuée ardente on the morning of December 4 were not accompanied by any vertical vulcanian cloud. Photographs taken during the first few minutes show the sky above the mountain top to be clear (figs. 5 and 7). On that morning Father Arthur SHEA was on Mindanao, just starting back to Camiguin Island. Driving along the north shore of Mindanao he observed a black cloud rushing down the slope of Hibok-Hibok toward Mambajao. The cloud swept down close to the ground, and was not accompanied at first by any cloud above the mountain. Father Shea lost sight of Hibok-Hibok temporarily as the vehicle in which he was riding rounded a turn in the road. When he saw it again, a few minutes later, a high cauliflower cloud was developing above the mountain (figs. 8-10). Photographs appear to indicate that this cloud rose largely from the mountain slope covered by the nuée ardente, rather than from the summit of the mountain (figs. 6 and 7).

Thus it is clear from the sequence of development of the explosion cloud, as well as the abundance of big blocks of dome debris, that the blast of the morning of December 4 was not a vertically initiated crateral nuée ardente (nuée ardente vulcanienne of Lacroix, 1930; St. Vincent vertical type of MacGregor, 1952). It was either a nuée ardente d'avalanche, or a nuée ardente d'explosion dirigée (Lacroix, 1930). Its higher temperature, larger size, and great force distinguishes it clearly from the earlier blasts of the eruption, and make it decidedly unlikely that it was a nuée ardente d'avalanche.

The large proportion of pumice and pumiceous ash in the deposits also indicates clearly that the nuées ardentes of December 4 and 6 were formed fundamentally by explosion of new magma, not simply by crumbling of the dense glassy dacite of the dome. We climbed the dome to its top in January, 1954, and paid special attention to the nature of the rocks composing it. Nowhere was more than a very small amount of pumice observed. No doubt the explosion undermined part of the carapace of the dome, with concomitant crumbling of the overlying portion providing the many blocks of glassy dacite transported seaward by the flow, but the mechanism supplying the basic initial impulsion was an explosion of new magma directed outward at a low angle.

At about 6:40 p. m. on December 4 an explosion threw a large number of blocks, some of them as much as 2 meters across, into a narrow sector just south of Itum. The area was examined in detail a few days later by Father Shea and Eugenio Omahoy. The blocks produced hundreds of impact craters, many of wich were still clearly visible in January, 1954. The largest crater observed was about 6 meters across and 2.5 meters deep. Some of the craters were on nearly flat ground; others were on a steep slope facing the summit of Hibok-Hibok. Only a relatively small amount of fine debris was associated with the blocks. The blocks had descended through heavy vegetation, breaking and scarring the trees before striking the ground. Study of these marks on the trees in relation to the craters indicated that the blocks had been traveling along paths that projected back to a point a little below the summit of the mountain. Allowing for the steepening of trajectory that certainly occurred during their flight, it is apparent that the blocks must have originated well below the summit of the dome. Just below the impact area of the blocks the major portion of the nuée ardente of December 4 was confined and somewhat deflected by the preexisting topography. If this deflection had not taken place the major portion of the cloud would have swept over the area covered by the blocks.

The distribution and impact pattern of the blocks indicate a considerable horizontal component of momentum. It appears unlikely that this could have resulted wholly from the impulsion of gravity driving the mobile cloud down the valley, particularly since the finer and more mobile upper part of the cloud (which is less controlled by gravity than the lower, denser part) did not sweep over the area to any extent. It seems clear that the blocks were hurled into the impact area by an explosion directed at a low angle. This explosion may have occurred within the descending nuée ardente itself, though in that case more fine debris would be expected to have accompanied the blocks. However, it appears much more probable that the explosion took place low on the flank of the dome. The explosion was associated with the generation of the nuée ardente, though it was not necessarily the cause of the latter. The fact that it did occur, together with the distinctly hotter and more mobile character of the nuées ardentes of December 4 and 6 as compared with the known nuées ardentes d'avalanche, suggests strongly that similar explosions directed outward at a low angle from points on the lower slopes of the dome were the cause of the major nuées ardentes.

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PLATES

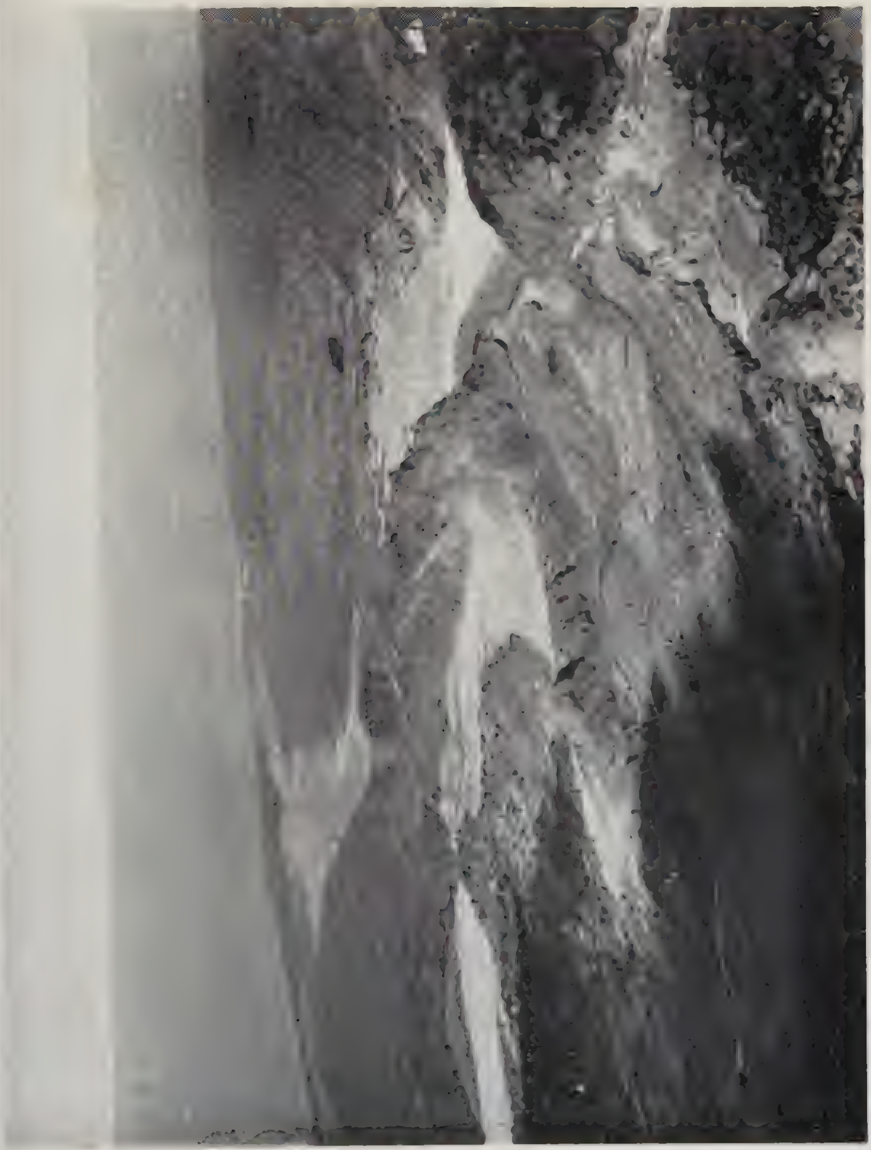

Fig. 2 – View down the avalanche valley from near the summit of Hibok-Hibok, in December 1953. The light areas are the nuée ardente deposits. Mambajao lies at the coast in the center of the picture. In the middle ground, the nuée ardente of December 6 spilled over the top of the Kanangkaan lava flow.

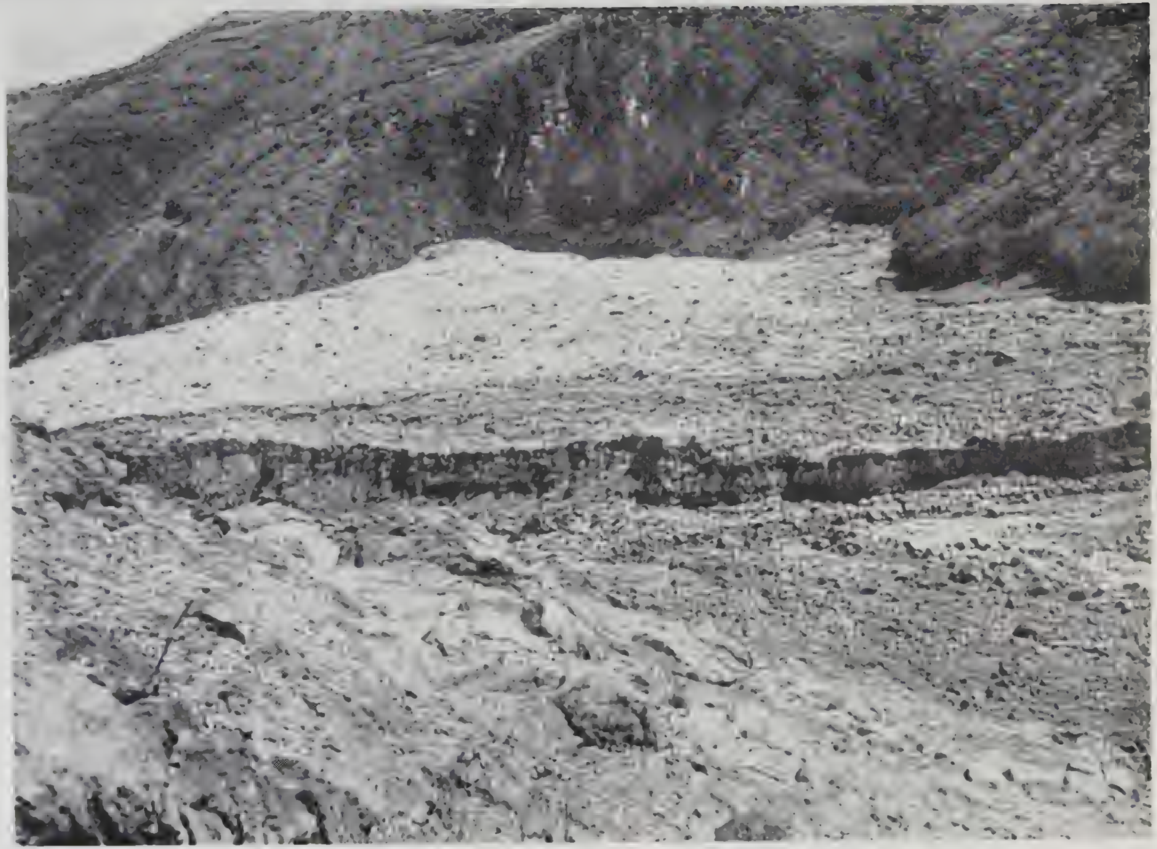

Fig. [illegible] - The deposits of the nuées ardentes of December. 1951, filling the bottom of the valley near Itum. The barranca has been cut into the flat surface of the deposits by stream erosion.

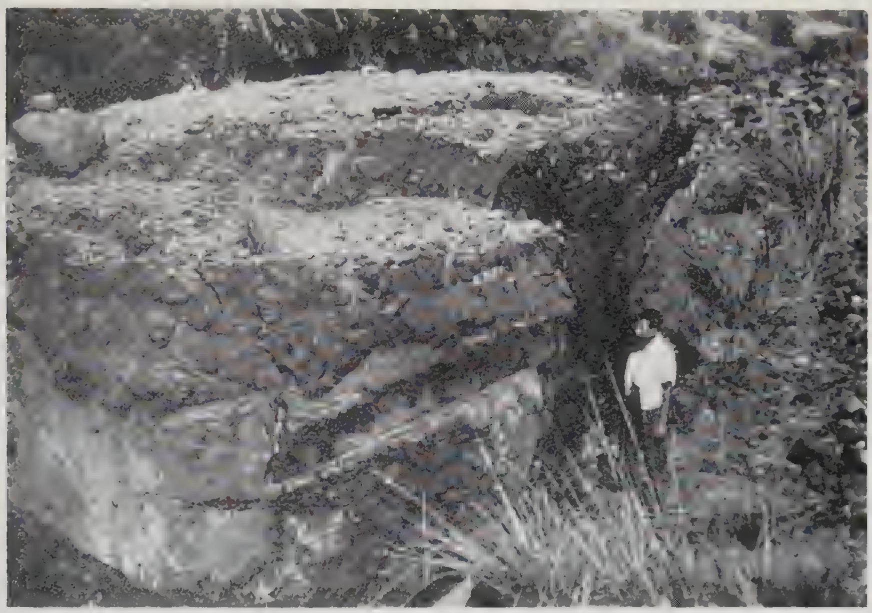

Fig. [illegible] Part of the large block on the deposit of the nuée ardente of December 6 that was torn apart by explosion after its emplacement.

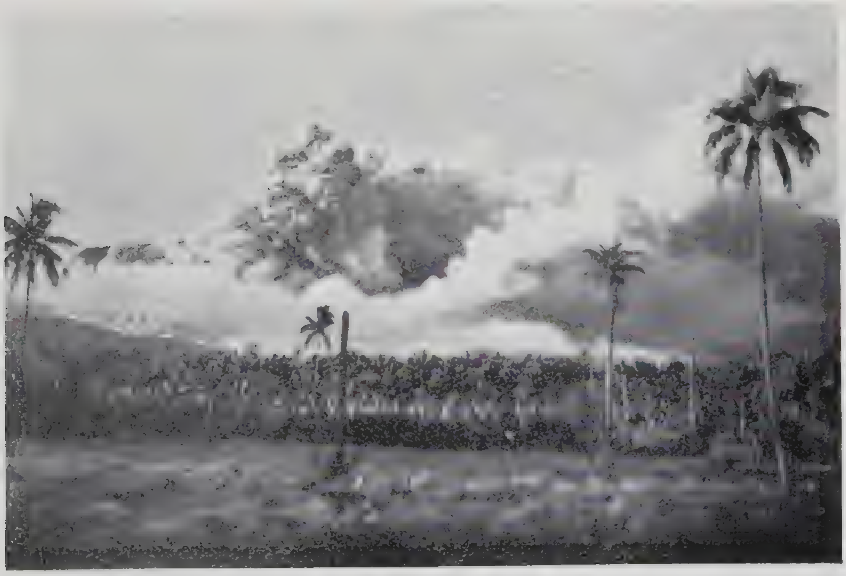

Fig. 5. - Early stage of the nuée ardente on the morning of December 4, 1951, seen from near Mambajao. Note the absence of any vertical vulcanian explosion cloud over the summit of the mountain. Photo by Hibok-Hibok Studio

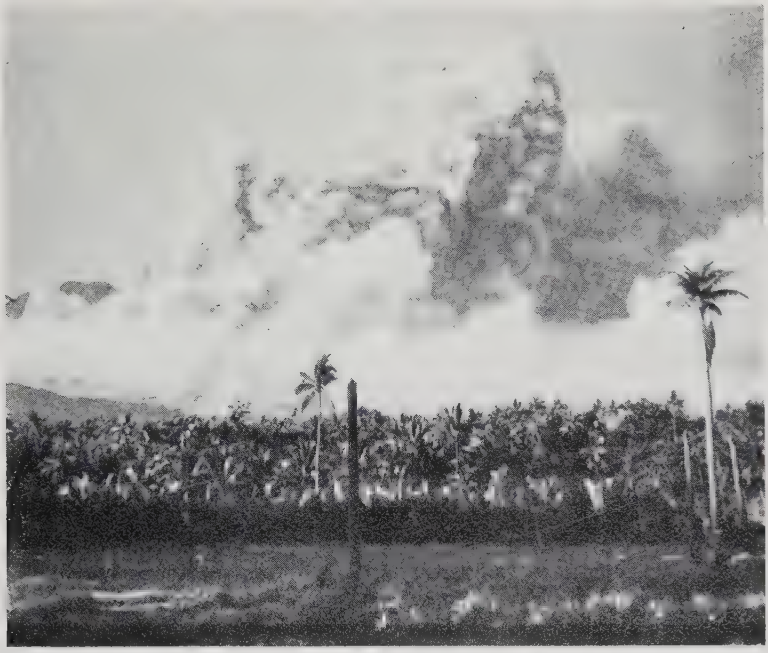

Fig. 6. - Dark cauliflower cloud rising over the course of the nuée ardente on the slope of the mountain. Photo taken a few minutes after that in fig. 5, by Hibok-Hibok Studio.

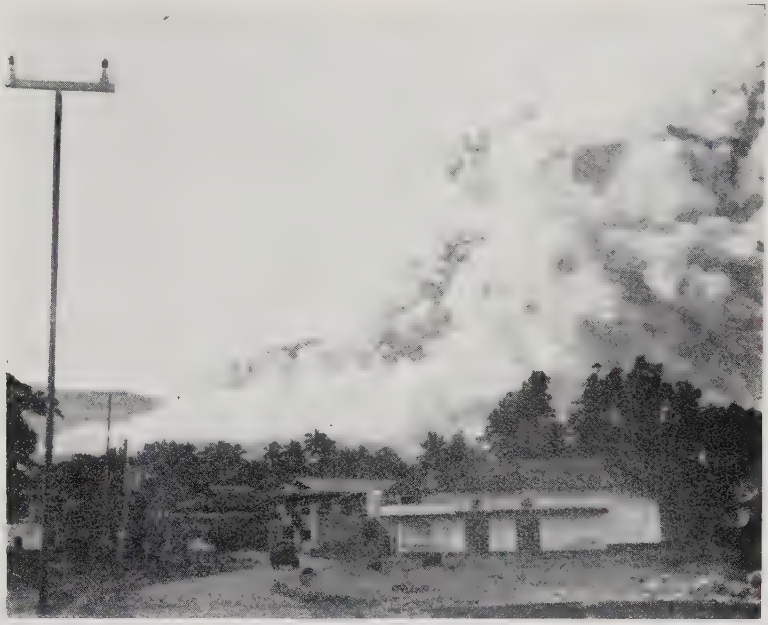

Fig. 7. - Early stage of the nuée ardente of December 4, 1951, seen from Mambajao. Photo by Hibok-Hibok Studio.

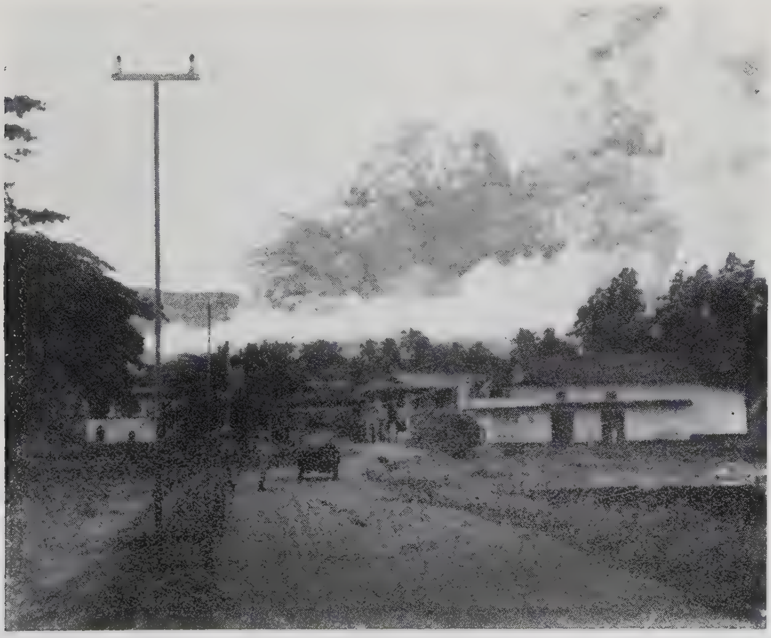

Fig. 8. - The nuée ardente of December 4, 1941, a minute or two after the stage shown in fig. 7.

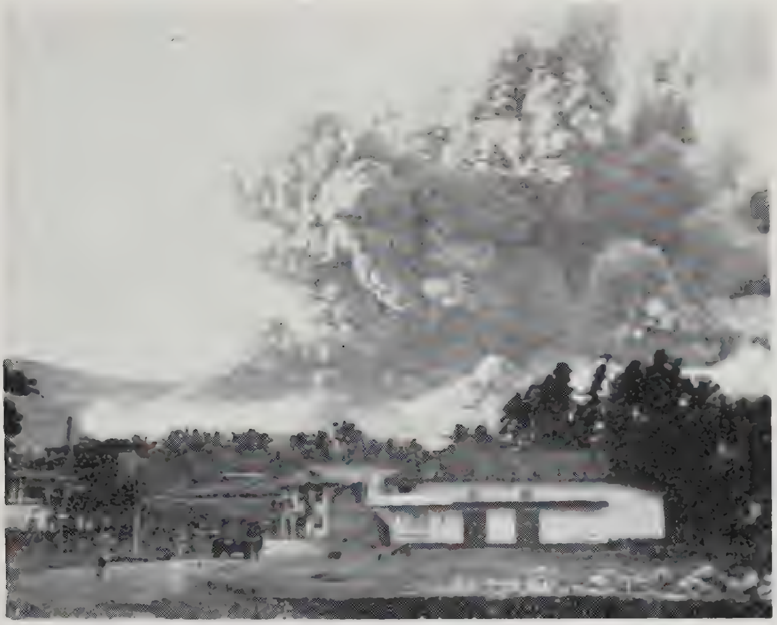

Fig. 9. - The nuée ardente of December 4, 1951, a few minutes after the view in fig. 8.

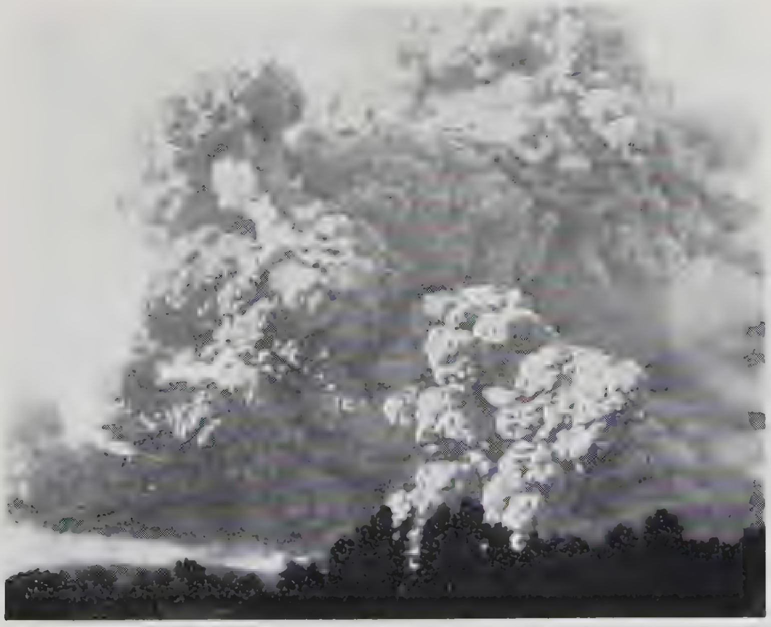

Fig. 10. - The nuée ardente of December 4, 1951, a few minutes after the view in fig. 9.

BERNARD GÈZE et ÉLISABETH JÉRÉMINE

Albert Michel-Lévy
1877-1955

S'il existe dans le monde scientifique, autant que dans celui des lettres ou des arts, une situation particulièrement délicate, c'est bien celle qui consiste à être le fils d'un père illustre ! Sans doute, les débuts dans l'existence en sont-ils certainement facilités, mais une personnalité, même brillante, aura toujours de la peine à s'imposer: elle risquera d'être considérée longtemps comme mineure par ceux qui ont connu ses antécédents...

Mais il est heureusement des cas où l'hésitation n'est pas permise et où chacun reconnaît à travers les divers représentants d'une même famille la persistance des qualités éminentes qui l'ont faite grande.

C' est en 1809 que naquit à Strasbourg Michel Lévy, sixième enfant de modestes commerçants en draperie. Grâce à sa vive intelligence, son labeur acharné et son dévouement extrême, il devint en peu d'années l'une des sommités médicales les plus écoutées de son temps. À quarante et un ans il avait atteint le plus haut grade dans ses fonctions de médecin militaire et entrait à l'Académie de Médecine dont il fut président en 1857. Curieusement, ce célèbre hygiéniste, décédé en 1872, peut être regardé comme l'ancêtre d'une dynastie de géologues qui fait honneur à la France (1).

En effet, son fils, Auguste Michel-Lévy, né à Paris en 1844, demeure l'une des grandes figures de la Pétrographie (2).

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(1) Voir l'Éloge de M. Michel Lévy prononcé dans la Séance annuelle de l' Académie de Médecine, le 13 décembre 1892, par M. J. Bergeron, Secrétaire perpétuel de l'Académie, Paris, Masson, 1893.

(2) Voir la Notice historique sur Auguste Michel-Lévy, Membre de la Section de Minéralogie, par Alfred Lacroix, Secrétaire perpétuel de l'Académie des Sciences, lue dans la séance publique annuelle du 21 décembre 1914, Paris, Gauthier-Villars, 1914.

On sait qu'il fut Inspecteur Général des Mines, Directeur du Service de la Carte géologique de la France, Professeur au Collège de France et Membre de l'Académie des Sciences. Ses travaux, dont beaucoup ont été réalisés en collaboration avec son maître et ami F. Fouqué ou avec son élève A. Lacroix, ont contribué largement à établir les fondements de l'emploi du microscope polarisant, de la détermination des minéraux des roches, de la classification des roches éruptives, des méthodes de synthèse des minéraux, etc. Consciemment ou non, tous les pétrographes sont actuellement des disciples de cette personnalité puissante qui disparut en 1911 en ne laissant que des regrets.

Ce grand savant n'était pas seulement un homme de laboratoire. Pendant toute sa jeunesse, il consacrait la belle saison à des levés de cartes en diverses régions et sa famille l'accompagnait le plus souvent. C'est ainsi, au cours d'une de ses tournées dans le Morvan, que, le 3 juillet 1877, naquit à Autun son fils Albert.

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Sous de tels auspices, la carrière d'Albert Michel-Lévy paraissait tracée d'avance. D'ailleurs, il nous dit lui-même: « C'est un rare privilège de commencer l'étude d'une science de la nature par l'observation sur le terrain, d'abord en écoutant, puis en questionnant des Maîtres que l'on accompagne (1) ». Cependant, il se dirigea d'abord vers l'Institut National Agronomique, où il obtint le diplôme d'Ingénieur Agronome en 1898, puis vers l'École Nationale des Eaux et Forêts de Nancy, d'où il sortit Garde Général en 1900.

En fait, il n'exerça que peu de temps le métier de forestier, et demanda son détachement d'un Service où il continua néanmoins à figurer hors cadres, jusqu'au grade de Conservateur qui lui fut octroyé en 1932.

Mais, dès 1901, sous l'heureuse influence de son père, il se consacra à la recherche, puis à l'enseignement scientifique.

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(1) Notice sur les titres et travaux scientifiques de Albert Michel-Lévy, Paris, Gauthier-Villars, 1938, p. 17.

D' abord préparateur de Fouqué au Collège de France, il acheva ses études en obtenant la Licence ès sciences naturelles en 1904 et le Doctorat en 1908. Peu après, en 1913, il fut appelé à enseigner la Pétrographie à la Faculté des Sciences de Paris, comme chargé de Conférences.

La guerre de 1914 interrompit alors ses travaux. Capitaine de chasseurs à pied, il fut blessé à deux reprises et reçut la Légion d'honneur et la Croix de guerre, ainsi que des décorations anglaises, russe, belge et roumaine. Moins apte à un service combattant, il termina la guerre comme Chef de Bataillon affecté à l'État-Major de l'Armée.

Le calme revenu, il reprit sa place en Sorbonne, où se déroula presque toute sa carrière. Quelques dates en précisent les étapes: Maître de Conférences en 1919, Professeur sans chaire en 1923, Professeur à titre personnel en 1936.

En 1940 seulement, par suite des mesures édictées contre les israëlites, il fut suspendu de ses fonctions. Sans doute, le Conseil d'État cassa-t-il rapidement cette décision, particulièrement inique dans son cas, mais il demeura dans le Midi de la France où il s'était réfugié avec sa famille et donna son enseignement à la Faculté des Sciences de Toulouse entre 1942 et 1944.

Après la Libération, il fut promu Professeur à la classe exceptionnelle et retrouva son Laboratoire à la Sorbonne, mais pour peu de temps, car la maladie l'obligea à demander une retraite anticipée en 1946. Sa féconde activité dut se restreindre progressivement et il s'éteignit le 2 mai 1955, entouré des siens, dans la paisible demeure parisienne qui avait vu aussi la fin de son père 44 ans auparavant.

A côté des fonctions normales, inhérentes à son enseignement, Albert Michel-Lévy fut aussi Collaborateur principal au Service de la Carte géologique de la France, Membre du Conseil supérieur d'Hygiène publique, Membre du Comité scientifique des Poudres, Président de la Société géologique de France, Président de la Société française de Minéralogie, enfin Président de l'Association de Volcanologie de l'Union géodésique et géophysique internationale pendant la longue période de 1936 à 1949.

Il fut élu Membre de l'Académie des Sciences en 1945 et atteignit le grade de Commandeur dans l'ordre de la Légion d'Honneur.

⁂

L'oeuvre d'Albert Michel-Lévy gravite autour de trois préoccupations essentielles qui peuvent paraître assez étrangères les unes aux autres et qui pourtant se sont succédées dans le temps d'une façon parfaitement logique: d'abord travaux sur le terrain, avec études pétrographiques au laboratoire, ensuite expériences sur les explosifs, enfin essais de synthèses de minéraux et de roches.

La première et la dernière de ces préoccupations correspondent strictement à la ligne des recherches auxquelles on peut dire qu'Albert Michel-Lévy était préadapté de par les travaux de son père, mais il est curieux de constater que le biais qui l'a conduit de la pétrographie classique à la pétrologie expérimentale est, en quelque sorte, une rencontre accidentelle et que, de celle-ci résulte précisément la partie de son oeuvre volcanologique la plus originale.

Ses travaux de géologie et pétrographie régionales ont porté principalement sur des fragments divers de la chaîne hercynienne en France: Morvan, Mâconnais, Beaujolais, Lyonnais, Vosges méridionales, Maures et Estérel, Montagne Noire.

En dehors des descriptions de détail du terrain, quelques grands faits ont été dégagés. On peut souligner, pour le Morvan, la découverte d'une faune à Goniatites et Clymenies du Famennien; la reconnaissance de la mise en place des granites à la fin du Tournaisien dans le Sud, à la fin du Viséen dans le Nord; la distinction de deux séries volcaniques, l'une sodique, du Famennien, l'autre potassique, du Viséen.

Dans le Mâconnais, le Beaujolais et le Lyonnais, où les formations sont analogues, la limite supérieure du métamorphisme granitique monte à la fin du Viséen. Dans les Vosges méridionales, il y a identité d'âge des plis hercyniens, avec mise en place du granite au Tournaisien. Dans les Maures et l'Estérel, les roches volcaniques sont permiennes et l'on peut suivre l'évolution des cristallisations successives dans les magmas rhyolitiques. Dans la Montagne Noire, le massif granitique alcalin du Mendic est d'âge antécambrien, tandis que les autres massifs granitiques voisins appartiennent au cycle hercynien.

Plus épisodiquement, Albert Michel-Lévy a étudié aussi d'autres régions. Par exemple, il a distingué les divers stades de mylonitisation des protogines du Mont Blanc et des Aiguilles Rouges; il a proposé de voir dans les conglomérats de Perrier (Puy-de-Dôme) le résultat de coulées boueuses produites à la suite d'explosions dans des cratères-lacs; il a examiné de nombreuses roches rapportées par E. Chaput des volcans de l'Anatolie centrale; enfin l'un de ses derniers travaux est consacré à des laves basaltiques trouvées par sondage dans les Petites Pyrénées au Nord de Saint-Gaudens et qui correspondent à des épanchements sous-marins d'âge Crétacé.

C'est sa rencontre avec l'Ingénieur général des Poudres H. Muraour, venu le consulter presque incidemment en 1928, qui explique la deuxième orientation des recherches d'Albert Michel-Lévy. En étroite collaboration, tous deux mettent au point la technique de la « micropyrotechnie » qui permet de suivre sous le microscope, et avec l'aide de l'appareil photographique ou cinématographique, les modalités d'explosions de particules infimes de corps détonants variés.

L'un des résultats scientifiques les plus importants est qu'une petite quantité d'un explosif très brisant, placé dans une rainure circulaire d'un bloc cylindrique de laiton et amorcé en un point du cercle, fournit au point opposé à l'amorçage une puissante luminosité en forme de colonne verticale, qui correspond à la rencontre de trains d'ondes de choc dont la vitesse de translation au départ atteint six à huit kilomètres par seconde. Cette rencontre détermine en outre des pressions très considérables, génératrices de très hautes températures.

Les effets de ces ondes de choc sont indépendants de ceux des gaz issus de la détonation et ils leur sont antérieurs. Quant à l'intensité du phénomène lumineux, elle varie considérablement suivant le milieu gazeux dans lequel se propagent les ondes de choc: elle est d'autant plus élevée que la chaleur spécifique du gaz entourant est plus faible et, à chaleur spécifique égale, elle est d'autant plus grande que la densité du gaz est plus forte.

Dans l'argon, pour une surface émettrice inférieure à deux centimètres carrés, l'intensité lumineuse est supérieure à celle du soleil pendant environ trois millionièmes de seconde, la pression instantanée est de l'ordre de 50 tonnes par centimètre carré et la température semble pouvoir atteindre 35.000 degrés.

En présence de ces résultats surprenants, Albert MICHEL-LÉVY émet l'hypothèse que les effets des détonations volcaniques sont comparables à ceux des détonations d'explosifs. Les luminosités violentes que l'on observe dans maintes éruptions seraient notamment dues à la rencontre d'ondes de choc et non à des phénomènes de flamme. De même, des destructions provoquées par les explosions péléennes, comme celle de Saint-Pierre de la Martinique en 1902, seraient causées par la transmission d'une onde de choc et non par l'apport de cendres brûlantes, qui n'arrivent que postérieurement aux destructions.

Ayant bien en mains cette nouvelle technique génératrice de hautes pressions et hautes températures, Albert MICHEL-LÉVY passe à la troisième orientation de ses travaux en utilisant les propriétés des explosifs pour tenter de réaliser la synthèse de minéraux et de roches non encore obtenus par les chercheurs antérieurs.

Déjà, vers 1905, avec les conseils de FOUQUÉ et d'Auguste MICHEL-LÉVY, il avait essayé la reproduction artificielle des roches acides dans un appareillage destiné à conserver la pression de l'eau aux températures du rouge sombre, avec un four électrique. Mais n'ayant pu obtenir des joints étanches, il avait rapidement renoncé à ces essais.

En 1938, il mélange intimement des poudres de minéraux, de roches et de produits chimiques avec de l'hexogène, explosif brisant finement cristallisé, dispose le mélange dans l'appareillage utilisé pour l'étude photographique des luminosité produites par les ondes de choc et place le tout dans une bombe d'acier de grand diamètre. À l'ouverture de la bombe, après détonation, il observe des sphérules vitreuses de 1 à 20 microns déposées sur les parois froides de la bombe.

Une deuxième série d'expériences, avec des modifications dans la constitution des bombes permet l'apparition d'édifices cristallins grâce au maintien jusqu'à trente jours de pressions de l'ordre de 4.000 kg. par cm^2 et de températures de 400 a 700° puis de 850° dans le four électrique. Successivement sont ainsi étudiés le rôle de la pneumatolyse, l'influence des minéralisateurs, la mobilité de la silice, le métamorphisme de roches diverses.

Travaillant en étroite collaboration avec son collègue et ami le minéralogiste Jean Wyart, Albert Michel-Lévy ne put réaliser son rêve de reproduire du granite, mais il obtint par ces procédés la synthèse de nombreux minéraux (orthose, anorthose, albite, anorthite, quartz, cristobalite, séricite, biotite, augite, corindon, magnétite, nickel magnétique, zincite, azotates, carbonates, etc.) et même de vraies roches acides (fines aplites formées de quartz et feldspaths alcalins).

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Dans cette science, d'une exposition un peu ingrate, qu'est la Pétrographie, Albert Michel-Lévy fut un professeur remarquable. Avec une parfaite simplicité et une clarté sans équivalent, il sut présenter à ses élèves de licence les principes et les problèmes de l'étude des roches au point de transformer les formules traditionnelles et forcément un peu dogmatiques en quelque chose de vivant et presque de passionnant.

Ses phrases, nettes et précises, étaient parfois égayées par une expression pittoresque qui réveillait les attentions. Au laboratoire, avec dévouement et bienveillance, il venait distribuer conseils et réflexions pertinentes. Pour ceux de ses disciples qui cherchaient à poursuivre une carrière dans la géologie, il savait, avec délicatesse, se préoccuper des situations financières individuelles et n'hésitait pas, sans promesses préalables, à faire tout son possible pour obtenir des aides importantes, fait d'autant plus notable que sa position personnelle le dispensait d'avoir à songer aux questions matérielles.

Sur le terrain, où il ne se rendait plus guère depuis longtemps que pour conduire ses élèves, il retrouvait une gaieté simple et franche, plutôt une euphorie discrète, qui lui permettait, sans peine, de faire partager ses enthousiasmes et de faire goûter pleinement à la « joie de connaître » chère au coeur de tout géologue. Nous le revoyons encore, présentant les admirables phénomènes de contact du granite de Flamanville, sur les rivages de la Manche, ou arpentant les routes d'Auvergne pour expliquer avec persuasion les phénomènes grandioses dont la reconnaissance par plusieurs générations de savants a permis de jeter les bases de la volcanologie.

Lorsqu'il recevait chez lui ses disciples préférés, ceux-ci étaient immédiatement saisis par l'ambiance à la fois austère et pleine de bonté dans laquelle il avait toujours vécu. On sait que son père, autoritaire et dominateur, mais droit, franc et profondément honnête, lui avait donné l'exemple. De toute évidence, il continuait avec naturel à respecter et à faire respecter des siens les mêmes grandes traditions.

Vers la fin de sa vie, alors qu'il n'était soutenu que par les soins constants et la vigilance de ses familiers, il accordait encore volontiers une entrevue à ceux dont il s'était fait des amis. Il semblait d'abord infiniment fatigué; pourtant lorsqu'était soulevée une question scientifique, il retrouvait toute son énergie, sa passion pour la recherche, et ne ménageait pas ses vues originales et ses conseils éclairés.

Sa volonté n'avait, en rien, été amoindrie par les épreuves douloureuses qui lui avaient été imposées. Il dut en subir de nombreuses: guerre, exil, pillage d'une partie de ses biens, enfin la plus atrocement cruelle, la perte de son seul fils, Roger, prisonnier en 1940, puis libéré comme Inspecteur des Eaux et Forêts à Besançon, qui, mêlé à la Résistance, fut repris et assassiné par les Allemands, en février 1944.

S'il fut ainsi lourdement frappé dans sa descendance, par elle il eut néanmoins de grandes joies, qui se sont prolongées jusqu'au dernier jour. Sa fille Hélène avait déjà réalisé d'intéressantes observations, par exemple sur les volcans de l'Escandorgue, dans le Midi de la France. Mais ce fut surtout sur sa cadette, Mireille, devenue Madame CHRISTOPHE, qu'il reporta tous ses espoirs. Dans le Laboratoire de Jean WYART, à la Sorbonne, celle-ci reprit dans des conditions moins difficiles le problème de la reproduction des minéraux, particulièrement de ceux dus au métamorphisme.

Il eut le bonheur de la soutenir dans ses débuts, de la conseiller et de la voir aboutir à de remarquables résultats. Le flambeau était passé de main en main, sans interruption malgré l'adversité...

Aujourd'hui, Albert Michel-Lévy nous laisse le souvenir d'un grand savant, que n'oublieront pas ceux qui ont eu le privilège de bénéficier de ses enseignements lumineux, de ses avis toujours bienveillants, de sa générosité et de son amitié.

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XIe Assemblée Générale de l'Union Géodésique et Géophysique Internationale

Toronto, Ontario, Canada, 1957

ASSOCIATION DE VOLCANOLOGIE

BUREAU CENTRAL INTERNATIONAL
DE VOLCANOLOGIE

Pour la correspondance:
Prof. FRANCESCO SIGNORE
Via Tasso 199
NAPOLI (Italie)

Naples, mai 1956

Mon cher Collègue,

J'ai l'honneur de vous faire savoir que la Onzième Assemblée générale de l'Union géodésique et géophysique internationale aura lieu à Toronto, Ontario, Canada (septembre 1957).

Je vous prie de vouloir me faire parvenir *avant le 30 avril 1957* vos propositions personnelles (ou celles du Comité national de volcanologie par vous éventuellement présidé) pour rédiger l'Ordre du jour des séances.

Chaque thème ou proposition doit être accompagné par un résumé.

Je porte en même temps à votre connaissance ce qui suit:

Dans la Réunion du Comité Exécutif de l' U.G.G.I. (Paris, 17 avril 1956) le Group de Travail pour la réorganisation de l'Association de Volcanologie, Proff. Rittmann, Rothé, Signore, Wadati, Wilson, a récommandé:

1. Que l'on change le nom de l'A.I.V. en Association Internationale de Volcanologie, de Composition de la Terre et de Géochronologie, mais que l'on garde le titre du Bulletin Volcanologique.

2. Que le champ d'action de l'A.I.V. soit agrandi et comprenne la géochronologie et la composition de la Terre.
3. Que des commissions pour la géochronologie et la composition de la Terre soient créées dans l'A.I.V.
4. Que le Comité Exécutif de l'A.I.V. comprenne le Président, le Secrétaire Général et trois Vice-Présidents, afin que chaque Commission soit représentée par un des Vice-Présidents:
   - Commission de paléovolcanologie (existant déjà)
   - Commission de géochronologie
   - Commission de composition de la Terre.
5. Que ces propositions soient discutées au cours de l'Assemblée générale de Toronto.
6. Que la publication du Catalogue des Volcans actifs soit continuée ainsi que celle des volumes supplémentaires.
7. Que la collaboration avec d'autres Associations soit accrue.
8. Que des symposia traitant de questions d'intérêt général soient tenus aussi souvent que possible.
9. Que les Associations de Volcanologie et de Séismologie et Physique de l'Intérieur de la Terre tiennent à Toronto des réunions communes à propos des sujets suivants:

   a) interpretation physico-chimique des termes magma, croûte et substratum;
   b) géochronologie et radioactivité;
   c) cartes de radioactivité.

Dans l'espoir que vous serez présent à cette session, je vous prie d'agréer l'assurance de ma parfaite considération.

Le Secrétaire général
F. Signore

Aux Présidents et Secrétaires des Comités nationaux de Géodésie et Géophysique.

Aux Membres des Sub-comités nationaux de Volcanologie.

XIth General Assembly of the International Union of Geodesy and Geophysics

Toronto, Ontario, Canada, 1957

ASSOCIATION OF VOLCANOLOGY

Address to:
Prof. FRANCESCO SIGNORE
Via Tasso 199
NAPOLI (Italy)

Naples, may 1956

Gentlemen,

I have the honour to inform you that the Eleventh General Assembly of the International Union of Geodesy and Geophysics will be held at Toronto, Ontario, Canada in September 1957.

I beg you to send me *before 30th of April 1957* your personal proposals (or those of the National Committee you are chairman of) regarding the program of our sessions.

Each proposal or subject should be accompanied by a short summary.

On this occasion I wish to inform you about the following items:

During the Meeting of the Executive Committee of the U. G. G. I. , on 17th of April 1956 at Paris, the Working Group for the reorganisation of the Association of Volcanology, consisting of the five members Rittmann, Rothé, Signore, Wadati and Wilson, has elaborated the following recommendations:

1. That the name of the A.I.V. be changed into: International Association of Volcanology, Constitution of the Earth and Geochronology, but that the title of the « Bulletin Volcanologique » be preserved as such.

2. that the activity of the A.I.V. be increased including Geochronology and Constitution of the Earth.
3. that, within the A.I.V., commissions be created for geochronoly and for the constitution of the earth.
4. that the Executive Committee of the A.I.V. be formed by the President, the General Secretary and three Vice-Presidents, so that each Commission be represented by a Vice-President, i.e.:
    Commission of Paleovolcanology (already existing)
    Commission of Geochronology
    Commission of the Constitution of the Earth.
5. that the above proposals be discussed during the General Assembly at Toronto.
6. that the publication of the Catalogue of the Active Volcanoes be continued as well as that of its supplementary volumes.
7. that the collaboration with the other Associations be increased.
8. that symposia, dealing with problems of general interest, be held as often as possible.
9. that the Associations of Volcanology and of Seismology and of the Physics of the Interior of the Earth shall have joined meetings at Toronto dealing with the following items:

    a) physico-chemical interpretation of the terms magma, crust and substratum.
    b) geochronology and radioactivity.
    c) maps of radioactivity.

The General Secretary
F. Signore

ASSOCIATION DE VOLCANOLOGIE DE L'U.G.G.I

XI^e Assemblée générale de Toronto 1957

PROGRAMME PROVISOIRE

3 - 7 Sept.:

a) Travaux sur les volcans actifs
b) Rapports nationaux
c) Travaux de paléovolcanologie.

9 - 11 Sept.:

a) Interprétation physico-chimique des termes magma, croûte et substratum. Rapporteur: Prof. A. Rittmann.
b) Géochronologie et radioactivité; cartes radio-géologiques. Rapporteur: Prof. J. T. Wilson.

Séances communes aux Associations de Volcanologie, Séismologie et Physique de l'Intérieur de la Terre.

12 - 13 Sept.:

a) Réorganisation de l'Association de Volcanologie.
b) Statut.
c) Élections.

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Part V. MELANESIA. - By N. H. FISCHER.

Part VI. CENTRAL AMERICA. - By F. MOOSER, H. MEYER-ABICH AND A. R. MCBIRNEY.

CONDITIONS GÉNÉRALES DE VENTE

1) Les commandes sont à adresser à: M. le Secrétaire de l'Association Internationale de Volcanologie - Prof. Francesco Signore - Via Tasso 199 - *Napoli* (Italie).

2) L'envoi est fait par les soins du Secrétariat dès réception du paiement par virement au: « Conto corrente n. 582 presso Banco di Napoli, Agenzia n. 4 (Vomero) Napoli, intestato al Segretario generale dell'Associazione Internazionale di Vulcanologia, Professore Francesco Signore » ou par chèque au Prof. Francesco Signore.

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BULLETIN D'INFORMATION DE L'U.G.G.I. - I.U.G.G. NEWS LETTER.

Publié par le Secrétaire Général G. Laclavère.
4e Année - No. 11 and 12, 1955; 5e Année - No. 13. 1956, Butterworths Scientific Pubblications, 88 Kingsway, London, W. C. 2.
Prix de chaque numéro: 800 Frs.

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